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ALGAE OF THE HAWAIIAN ARCHIPELAGO. II

VAUGHAN MACCAUGHEY

The following list will indicate the specific content of the alga flora of the Hawaiian Archipelago. In so far as has been possible to obtain published records, in addition to the author's material, the list comprises practically all known Hawaiian algae. As the field has never been intensively surveyed in its entirety, there is undoubtedly a vast number of forms still undescribed. This is particularly true of the phytoplankton. The list includes brief characterizations, with special reference to habitat and geographical distribution. Items of special interest, such as economic uses, are also noted, although it has been necessary to restrict such data sharply for sake of compactness. The list is offered as a reconnaissance, and carries no implication of completeness.

The sequence of families is that of ENGLER and PRANTL; the sequence of species is that of DETONI (*Sylloge Algarum*). The determinations are principally those of TILDEN, LEMMERMANN, REED, and SETCHELL; in many cases material collected by the author has been compared with the original descriptions, and the representative stations or habitats have been confirmed, redefined, or extended. The literature concerning the habitats and ecological relations of Hawaiian algae is very scanty; the chief aim of the present paper has been that of summarizing available data, and thus indicating the need for more detailed and intensive investigations.

Schizophyceae

CHROOCOCCACEAE

Chroococcus turgidus (Kuetz.) Naegeli.—In shallow stagnant pools; collected on the slopes of Mauna Kea, Hawaii.

C. macrococcus (Kuetz.) Rabenh.—In shallow stagnant pools; collected on the slopes of Mauna Kea, Hawaii.

Gloeocapsa polydermatica Kuetz.—Plant colony gelatinous and slimy; dull green or dusky olive, often very dark; on wet cliffs and rock surfaces; from sea level up through the rain forests.

G. quarternata (Breb.) Kuetz.—Forms a gray-green or light olive mucilaginous coating on wet cliffs; abundant in the humid zones, especially near waterfalls.

G. magma (Breb.) Kuetz.—Forms a grumous, crustaceous, coppery purple mass on wet stones, in and along mountain streams, mostly between 1000 and 6000 ft.

G. thermalis Lemm.—Colonies mucous, hyaline or dark purple; characteristic of warm pools on Hawaii, especially in the Puna district.

Chondrocystis Schauinslandii Lemm.—Colony cushion shaped, widely expanded, up to 35 cm. high, cartilaginous, soft and fragile, incrusted with lime at the base; recorded only from the Laysan Island lagoon.

Gloeothece fuscolutea Naegeli.—Colonies soft, gelatinous, bright blue-green, often covering the surface of the water in the lowland rice fields and among taro patches (loi).

Aphanothece Naegeli Wartmann.—Colonies gelatinous, forming small, soft, olive-brown lumps along the margins of waterfalls, among mosses, liverworts, etc., in the rain forests and on wet cliffs.

A. prasina A. Braun.—Colonies soft, gelatinous, more or less globular; bright emerald green; forming free swimming, tuberculose, globose, or flattened masses; floating in brackish water in stagnant pools, rice patches, and similar situations.

Gomphosphaeria aponina Kuetz.—Colonies spherical, mucous, solid, and free swimming; collected among marine algae at Laysan Island.

Coleosphaeriopsis halophila Lemm.—Colonies spherical, gelatinous, hollow, known only from the lagoon of Laysan Island.

Merismopedium glaucum (Ehrenb.) Naeg.—Colonies flat, free floating, in shallow, sluggish water, such as rice fields, taro loi, etc.; sometimes very abundant, especially in late summer (Oahu).

CHAMAESIPHONACEAE

Xenococcus laysanensis Lemm.—Epiphytic, disk-shaped colonies; collected on marine algae at Laysan Island.

X. Kerneri Hansg.—Colonies irregularly expanded, crustaceous; fairly abundant in ditches and taro patches throughout the lowlands; sometimes epiphytic.

Chamaesiphon curvatus Nordst.—Epiphytic; collected among filaments of *Cladophora longiarticulata* in taro patches and ditches; not common; var. *elongatum* Nordst. is found in similar situations.

OSCILLATORIACEAE

Oscillatoria sancta Kuetz.—Colonies or plant mass dark lead colored, "becoming violet when dried and tinting the paper a beautiful violet" (TILDEN); forms a reddish brown or grayish skin on the wet sides of cliffs, waterfalls, ditches, and other moist, earthy places.

O. Bonnemaisonii Cruan.—Trichomes form loose and regular spirals; epiphytic on marine algae in Laysan Island waters; mixed with other algae, floating in lagoons within the reefs, Hawaii and other islands.

O. corallinae Gomont.—Trichomes gregarious, forming a fine, delicate coating on the surface of larger algae; collected at Laysan in washings from marine algae.

O. laetevirens Crouan.—Plant mass thin, membranaceous, bright blue-green; abundant, forming a delicate stratum covering the bottoms and sides of tidal pools in rocky places along the platform reefs; also collected among washings from marine algae at Laysan.

O. formosa Bory.—Plant mass dark blue-green; common on wet cliffs and near waterfalls, in the montane rain forests; also on the walls of wet caverns, near the mouths; these latter situations are often rich in blue-green algae.

Trichodesmium Thierbaultii Gomont.—Colonies green, forming extensive disconnected "sea blooms"; collected in plankton between Hawaii and Laysan.

T. contortum Wille.—Colonies bright yellow, spirally twisted; habit like the preceding; collected in plankton between Hawaii and Laysan.

Spirulina major Kuetz.—Plant mass dark blue-green; usually scattered among other algae, as on the sides of wet cliffs and near the mouths of the very numerous moist caverns or "lava-tubes" which honeycomb the Hawaiian mountains, from sea level to the highest summits.

S. subtilissima Kuetz.—Plant mass mucous, dark green; collected at Laysan Island in washings from marine algae.

Phormidium Crosbyanum Tilden.—Plant mass 2 cm. thick by 5 cm. diameter, impregnated with lime, somewhat hard, bluish green to reddish brown; forming flattened globose cushions on rocky shelves along the coral reefs and ledges, between tide marks.

P. papyraceum (Agardh) Gomont.—Plant mass expanded, glistening, thin, leathery, dark green; on wet rocks and cliffs, and around water-tanks, troughs, flumes, etc.; abundant.

P. laysanense Lemm.—Known only from Laysan Island, where it was collected on *Turbinaria*.

P. favosum (Bory) Gomont.—Plant mass moderately expanded, papery or thick, attached at base, floating; on sides and bottoms of irrigation ditches and troughs, tanks, etc.; not uncommon.

Lyngbya mucicola Lemm.—Epiphytic; known only from Laysan Island, where it was collected on *Chondrocystis Schauinslandii*.

L. rivulariarum Gomont.—Occurring in masses of *Nostoc*, in lowland ditches and taro patches; not uncommon.

L. subtilis W. West.—Filaments solitary and scattered; in pools and ditches in the lower zones of the larger islands.

L. distincta (Nordst.) Schmidle.—In irrigation ditches and streams; fairly plentiful; also found among the filaments of such other algae as *Pithophora* spp.

L. cladophorae Tilden.—Epiphytic on filaments of *Cladophora*, in the mountain streams.

L. Meneghiniana (Kuetz.) Gomont.—Plant mass up to 1 cm. high; caespitose, fasciculate, mucous, dull blue-green; collected on marine algae at Laysan; not known from the other islands.

L. semiplena (C. Agh.) J. Agh.—Plant mass rarely higher than 3 cm., caespitose, extensive, mucous, usually dull yellowish green or dark green; occurs in the rocky basins of tidal pools along the platform reefs of such islands as Oahu and Kauai; also collected on marine algae at the Laysan atoll.

L. confervoides C. Agh.—Plant mass 5 cm. high, caespitose, extended, fasciculate, mucous, dull yellowish or dark green; fairly common on rocky shores and in tidal pools.

L. aestuarii (Mertens) Liebman.—Plant mass widely extended, either forming a compact woolly layer on moist earth, or a floccose mass floating in water, blackish or dull blue-green; common in ditches and muddy taro patches, forming a skin over the substratum; also on sandy beaches.

forma *natans* Gomont.—Plant mass covered with water; at first attached to wet earth, later floating; filaments loosely entangled; floating in fresh water lagoons, rice fields, taro patches, etc.

forma *aeruginosa* (Agh.) Wolle.—Plant mass dark blue-green; forming conspicuous patches in shallow water of rice fields, taro patches, and similar situations.

L. majuscula (Dillwyn) Harvey.—Plant mass up to 3 cm. high or long; widely expanded; dark blue to yellowish green; filaments very long; epiphytic on other marine algae, in shallow waters along the coral reefs.

L. Martensiana Menegh.—Plant mass caespitose, blue-green; occurring on twigs, etc., under dripping water, under flumes, and tanks, and near waterfalls in the mountains; not uncommon.

L. perelegans Lemm.—Epiphytic; known only from Laysan Island, where it was collected on other marine algae.

L. Kuetzingii var. *distincta* (Nordst.) Lemm.—Occurs on the lowlands, in ditches and shallow ponds; epiphytic on such forms as *Pithophora* and *Cladophora*.

Hydrocoleus cantharidosmus (Mont.) Gomont.—Plant mass up to 2 cm. high, caespitose, slippery, olive or dark blue-green; growing with other algae in shallow waters along the coral reefs and beaches.

Inactis hawaiiensis (Lemm.) DeToni.—Filaments solitary, growing in a gelatinous mass formed by other algae; collected in warm pools on the Island of Hawaii, in company with *Gloeocapsa*, *Stigonema*, etc.

Microcoleus paludosus (Kuetz.) Gomont.—Filaments entangled, growing among other algae or forming a blackish or blue-green stratum; together with other algae it forms a layer covering rocks on the bottoms and sides of the "Green Lake" in Puna, Hawaii.

Catagnymene pelagica Lemm.—Unicellular, free floating filaments; collected in plankton between Hawaii and Laysan.

C. spiralis Lemm.—Habitat as for the preceding species; collected in plankton between Hawaii and Laysan.

Haliarachne lenticularis Lemm.—Filaments multicellular, free floating in globose or elongate colonies; collected in plankton between Hawaii and Laysan.

NOSTOCACEAE

Nostoc punctiforme (Kuetz.) Hariot.—Colonies small, globose, scattered or confluent; frequent on the wet walls of ditches and taro patches.

N. paludosum Kuetz.—Colonies very minute, scarcely visible, punctiform, gelatinous; in shallow ditches and pools.

N. Linckia (Roth) Bornet.—Colonies of various sizes, finally clathrate-fenestrate and irregularly torn, blue-green or violet; occurs with *Conferva sandwicensis* and other algae in shallow pools, taro loi, swampy places, etc., at low altitudes.

N. piscinale Kuetz.—Fairly abundant in late summer in rice fields, taro patches, irrigation ditches (au-wai), etc.

N. spongiaeforme Agardh.—Colonies at first minute, finally expanded, verrucose, bullose; in taro patches and other warm, shallow, muddy bottomed waters; fairly plentiful.

N. foliaceum Mougeot.—Colonies gelatinous, spongy, lacunose; in globules among mosses and liverworts on wet cliffs in the montane rain forest zone, and in the vicinity of waterfalls; not recorded from the lowlands.

N. commune Vaucher.—Colonies spreading out as undulating, folded, fleshy, torn or perforated sheets, leathery on the surface;

common around water troughs, tanks, flumes, and similar moist situations.

N. verrucosum (Linn.) Vaucher.—Colonies often gregarious, up to 10 cm. in diam.; at first solid, gelatinous, firm, spherical, later hollow and torn; forming small, black-green, shotlike balls, covering the sides of pools in falls and rapids of the streams in the montane rain forests; not uncommon.

Nodularia hawaiiensis Tilden.—Plant mass or colony stringy, dark green, in tufts along the outer margins of the coral reefs; constantly washed by the surf; fairly common.

Anabaena variabilis Kuetz.—Colonies gelatinous, spreading on damp soil or floating free, dark green; on bottoms and sides of irrigation ditches, taro patches, and other moist places; this, like the following species, is usually found in connection with other algal forms.

A. catenula (Kuetz.) Born. and Flah.—Colonies gelatinous, floating, blue-green; frequent in stagnant water of rice fields and taro patches; sometimes in mountain streams, but not recorded from high altitudes.

A. confervoides Reinsch.—Colonies thin; floating in taro patches and other shallow water; sometimes rather abundant, but usually rare.

Cylindrospermum stagnale (Kuetz.) Born. and Flah.—Colonies floccose, expanded, indefinite, mucous; attached or floating; on wet cliffs and in the vicinity of waterfalls, chiefly in the rain forests.

C. catenatum Ralfs.—Colonies mucous, orbicular-confluent, indefinite, blackish green; along the mountain streamways, on rocks and wet cliffs; abundant in certain localities.

Richelia intracellularis J. Schm.—Endophytic, with single trichomes; found living in the cells of *Rhizolenia styliformis* and *Hemiaulis delicatus;* collected in plankton between Hawaii and Laysan.

Aulosira Schauinslandii Lemm.—Filaments free and equal; scattered or fasciculate; collected on *Turbinaria* at Laysan.

Michrochaete vitiensis Askenasy.—Colonies loosely caespitose, short, tomentose; collected growing on *Liagora coarctata* at Laysan.

Hormothamnion solutum Born. and Grunow.—Plant mass floccose, entangled, mucous, green or blue-green; not uncommon here and there along the coral reefs, in shallow waters and in tidal pools.

SCYTONEMACEAE

Plectonema nostocarum Bornet.—Filaments graceful, elongate, at first much branched, later sparingly branched; collected in warm pools in the vicinity of Kilauea Crater, an active volcano on the island of Hawaii.

Scytonema rivulare Borzi.—Colonies widely extended, woolly, blackish, tending toward reddish or brown; forming dark brownish or purple-red cushions on stones in the mountain streams; plentiful.

S. crispum (Agh.) Bornet.—Colonies caespitose, entangled, woolly, green, becoming brown or olive; in ponds, rice fields, taro patches, and other quiet or stagnant waters on the lowlands.

S. azureum Tilden.—Cell contents deep purple-blue; with other thermophilous algae forming a layer covering rocks on the bottoms and sides of hot springs in the Puna district, Hawaii.

S. varium Kuetz.—Colonies 2–3 mm. high, cushion-shaped, bluish green or brownish; often found on wet cliffs near waterfalls, chiefly in the rain forests.

S. javanicum (Kuetz.) Bornet var. *hawaiiensis* Lemm.—Colonies cushion-shaped, dark blue-green; collected among the wet mosses, etc., in the forests near Kilauea Crater, Island of Hawaii.

S. ocellatum Lyngb.—Colonies cushion-shaped, black or gray, becoming bluish; on moist shaded rocks and wet cliffs.

S. guyanense (Montagne) Born. and Flah.—Colonies dense, cushion-shaped, 1–2 mm. thick, widely expanded, blackish green; on moist stones.

S. mirabile (Dillwyn) Born.—Colonies woolly, widely expanded, spongy tomentose, brownish black or blackish green; collected in shallow pools on the slopes of Mauna Kea, Hawaii.

S. fuliginosum Tilden.—Colonies thin, bluish green; forms thin layers on the bottoms of shallow tidal pools, along the platform reefs and rocky shores; fairly common.

Tolypothrix lanata (Desv.) Wartmann.—Colonies caespitose-floccose, blue-green, becoming brownish with age; found in shallow

stagnant pools on the slopes of Mauna Kea, adhering to leaves, etc., in the water.

T. distorta (Hofman-Bang) Kuetz.—Colonies caespitose-floccose or cushion-like, blue-green or brownish; forming tufts or cushions on stones in the mountain streams; plentiful in the montane rain forest zone.

STIGONEMACEAE

Hapalosiphon fontinalis (Agh.) Bornet.—Colonies dull blue-green, 3 mm. high; found in shallow stagnant pools on Mauna Kea, adhering to leaves and other litter.

Fischerella ambigua (Naeg.) Gomont.—Colonies crustaceous, orbicular, up to 1 mm. thick, brown becoming black; on moist soil on shady places, on the lowlands, and in the rain forests.

F. thermalis (Schabe) Gomont.—Colonies 0.5 mm. thick, cushion-shaped, woolly, expanded, blackish olive or blue-green; collected in warm pools in the vicinity of Kilauea Crater.

var. *mucosa* Lemm.—Habitat as for the species; luxuriant algal growths occur in these warm springs.

Stigonema aerugineum Tilden.—Colonies forming a brown, membranous layer on the bottoms of shallow quiet pools.

S. ocellatum (Dillwyn) Thuret.—Colonies cushion-shaped, woolly, brownish; frequent in quiet shallow pools.

S. minutum (Agh.) Hassall.—Colonies crustaceous or cushion-like, thin, fragile, blackish; collected on moist stony soil in the vicinity of Hilo, Hawaii.

RIVULARIACEAE

Calothrix confervicola (Roth) Agh.—Filaments gregarious, stellately fasciculate, attached, rigid; collected as epiphytes on marine algae, at Laysan.

C. aeruginea (Kuetz.) Thuret.—Filaments forming a somewhat continuous light blue-green layer on the surfaces of larger algae; common in tidal pools along the coral platforms and rocky shores.

C. crustacea Thuret.—Colonies caespitose, velvety, widely expanded, blackish green or brownish; epiphytic on other algae in tidal pools and along the reefs.

C. fusca (Kuetz.) Bornet and Flah.—Filaments scattered or gregarious; living within the colonies of various gelatinous algae; in ditches, taro patches, and rice fields.

C. sandvicensis (Nordst.) Schm.—Epiphytic on filaments of *Pithophora affinis*, in shallow water on the lowlands.

C. rhizoleniae Lemm.—Epiphytic on *Rhizolenia* and *Hemiaulus;* collected in plankton between Hawaii and Laysan.

Rivularia natans (Hedwig) Welwitch.—Colonies spherical, hollow, soft, dull olive-green; forming soft brown velvety masses, in rice fields and taro patches; common on the lowlands.

Chlorophyceae

SPHAERELLACEAE

Haematococcus pluvialis Flotow.—Occurs throughout the islands in shallow pools and streams, often forming reddish patches; it is a cosmopolitan species.

H. thermalis Lemm.—Abundant in the warm springs of the Puna district, Hawaii, and endemic to this region.

VOLVOCACEAE

Gonium sociale (Duj.) Warm.—Occurs in ponds, taro patches, etc., throughout the islands.

Other well known genera, such as *Volvox*, *Pandorina*, and *Eudorina*, have not been reported as yet from the islands.

TETRASPORACEAE

Dactylococcus infusionum var. *minor* Nordst.—A widely known species, frequent in streams and shallow waters.

Dictyosphaerium pulchellum Wood.—A fairly common species.

PLEUROCOCCACEAE

Gloeocystis gigas (Kuetz.) Lagerh.—Has been recorded from the swamps on the middle slopes of Mauna Kea, Hawaii.

Raphidium polymorphum Fres.—A cosmopolitan species; occurs throughout the islands in fresh waters.

Schroederia setigera Lemm.—In pools and streams.

Closteriopsis longissima Lemm.—In pools and streams.

Oocystis Naegeli A. Br.—Has been collected in swamps on the middle slopes of Mauna Kea, Hawaii.

Scenedesmus quadricauda (Turp.) Breb.—In pools and reservoirs on all the islands; var. *oahuensis* Lemm. has been collected on the lowlands of Oahu.

CHARACIACEAE

Characium ensiforme Herm.—Has been reported from the swamps on the slopes of Mauna Kea.

C. minutum A. Br.—In wet caverns and other moist habitats.

C. groenlandicum Richter.—Found growing on crustaceans in fishponds on the island of Molokai.

HALOSPHAERACEAE

Halosphaera viridis var. *gracilis* Lemm.—Collected in plankton between Hawaii and Laysan.

HYDRODICTYACEAE

Pediastrum integrum var. *Braunianum* (Grun.) Nordst.—Pools and streams.

P. Boryanum (Turp.) Menegh.—Pools and streams.

P. duplex var. *clathratum* A. Br.—Pools and streams; var. *reticulatum* Lagerh. occurs in the same habitats.

P. tetras (Ehrenb.) Ralf.—Pools and streams.

P. bidentulum var. *ornatum* Nordst.—Stagnant shallow waters.

Hydrodictyon reticulatum (L.) Lagerh.—Plentiful in rice fields, taro patches, and other shallow waters; it is called *pala-wai* by the native Hawaiians, and sometimes used by them for food. The native name is also applied to several other green fresh water algae.

OPHIOCYTIACEAE

Ophiocytium gracilipes A. Br.—A free swimming form, in shallow waters, and also in wet caves at higher levels.

CONFERVACEAE

Conferva bombycina var. *minor* Wille.—Cosmopolitan.

C. sandwicensis Agh.—Endemic; in rice fields, pools, and streams; filaments very fine and silky.

ULVACEAE

Monostroma spp.—Several unidentified species occur in brackish pools and lagoons along the reefs.

Ulva rigida Agh.—Occurs along the coral reefs of the larger islands and also the atolls.

U. fasciata Delile.—Thallus stipitate, simple or divided into acute segments; fairly common along coral reefs and beaches.

U. lactuca L. forma *genuina* Hauck.—This and var. *laciniata* (Wulf.) J. Agh. are common in shallow waters along the coasts and reefs. Frequently great quantities are thrown up on the beaches by high tides or by kona storms. *U. fasciata* is known to the natives by the names *limu paha-paha* or *limu pala-haloha*. *U. lactuca* is called *limu lipa-laha-laha* or *limu pa-ka-ea*. These grow in quiet water near the shore and are easily gathered. When air dry these species have about 18 per cent water, 14 per cent protein, 50 per cent starches, sugars, etc., and 15 per cent ash. They are commonly used as a salad food by the natives, and comprise an important element in the food of the reef inhabiting fishes.

Enteromorpha flexuosa (Wulf.) Agh.—Very common on stones, along the shores and in the harbors; cosmopolitan.

E. Hopkirkii Agh.—An obscure species.

E. intestinalis (L.) Link.—Cosmopolitan, with numerous varieties and forms; abundant in Hawaiian waters.

E. Linza (L.) J. Agh.—Cosmopolitan, with several forms; abundant in Hawaiian waters.

E. plumosa Kuetz.—Cosmopolitan; not uncommon in Hawaii.

E. prolifera (Muell.) J. Agh.—Cosmopolitan; var. *tubulosa* Kuetz. occurs in brackish pools and ditches.

E. compressa (L.) Grev.—Cosmopolitan, with numerous varieties; var. *trichodes* Kuetz. is recorded from brackish situations.

All of the Hawaiian species of *Enteromorpha* grow in shallow salt or brackish waters along the coasts, and in brackish pools and ditches. They are usually abundant at the mouths of streams, especially on the islands of Kauai and Oahu. They are easily gathered, and are all considered edible by the natives. These algae, known as *limu ele-ele*, are among the most abundant, most popular, and most widely used of the edible algae. They are com-

monly on sale in the native markets. Chemical analyses of the air dry material show about 13 per cent water, 12–19 per cent protein, 50 per cent fats and carbohydrates exclusive of crude fiber, and 10–20 per cent ash.

ULOTHRICHIACEAE

Ulothrix subtilis Kuetz. and *U. minulata* Kuetz.—These two species are common in rice fields, taro patches, ditches, and similar situations; the yellow-green, decumbent, soft, hairlike fleece is attached to the bottom or rocks; under dripping water it forms a bright green incrustation.

CHAETOPHORACEAE

Stigeoclonium falklandicum Kuetz.—Called *limu pala-wai* or *limu li-pala-wai* by the natives, and used by them for food; occurs in streams and pools; fairly abundant.

S. amoenum Kuetz.—Called *limu hulu-ilio;* grows in brackish ponds and ditches near the sea; it is eaten by only a few of the natives; a cosmopolitan species with many varieties.

S. tenue Kuetz.—One of the algae most common on the vertical cliffs of waterfalls; in these situations it frequently becomes 12–14 inches long; like the preceding, it is a cosmopolitan species with many varieties.

Draparnaldia macrocladia Nordst.—Occurs in streams and pools; fairly common in Manoa, Núuanu, Kalihi, etc.; endemic.

Aphanothece repens A. Br.—Occurs in taro patches, swamps, etc.; often epiphytic on such plants as *Cladophora;* also in most caverns, on the walls and floors, ex. Makiki Valley; a cosmopolitan species, occurring in Europe and New Zealand.

Chaetosphaeridium globosum (Nordst.) Klebahn.—Widely distributed in fresh water; thallus subglobose, of branched procumbent filaments.

OEDOGONIACEAE

Oedogonium obsoletum Wittr.—In brackish waters; also in Europe and North America.

O. globosum Nordst.—In streams; recorded only from Hawaiian Islands.

O. crispum var. *havaiense* Nordst.—In swamps and pools; a cosmopolitan species with numerous varieties.

O. Pringsheimii forma *pachydermatosporum* (Nordst.) Hirn.—Collected in the Mauna Kea swamplands; a cosmopolitan species with numerous varieties.

O. acrosporum var. *majusculum* Nordst.—Collected in the Mauna Kea swamps; another cosmopolitan species with numerous varieties.

O. longicolle Nordst.—In pools and ditches; there are several varieties in Hawaiian waters.

A number of the species of *Oedogonium* are plentiful in the mountain streams and in the vicinity of waterfalls.

Bulbochaete varians Wittr. var. *havaiensis* Nordst.—Widely distributed in temperate regions as well as in the tropics.

B. rectangularis Wittr. var. *hiloensis* Nordst.—Another widely distributed species with numerous local varieties.

COLEOCHAETACEAE

Coleochaete orbicularis Pringsh.—Thallus minute, orbicular, 2–3.5 mm. diameter; filaments numerous, articulate; cosmopolitan.

C. irregularis Pringsh.—Thallus irregular, bright green, filaments decumbent; cosmopolitan.

CLADOPHORACEAE

Chaetomorpha pacifica Kuetz.—Abundant along the shores; occurs in all tropical waters; filaments grass green, coarse and rigid.

Cladophora fracta (Dillw.) Agh.—In streams and damp caverns; a cosmopolitan species with numerous varieties.

C. inserta Dickie.—In brackish pools along the coasts.

C. Nordstedii DeT.—In pools and swamps of fresh water; rare.

C. composita Harv. and Hook.—Thallus pulvinate, spongiose, pale green; filaments delicate membranous, pellucid.

C. nitida Kuetz.—This species is called *limu hulu-ilio* (dog's hair) by the natives, and is sometimes used for food; it occurs in mountain streams and pools.

C. composita contracta Brand.—Found along the leeward shores of the island of Oahu.

C. Montagnei Waianeana Brand.—This and the preceding occur in shallow waters along the coral reefs; the species is Cuban.

C. antennina (Bory) Kuetz.—This and several other species are used locally by the natives for food, chiefly on the islands of Maui and Hawaii; they are called *limu hulu-ilio*, *limu ilio*, or *limu manu*.

BRYOPSIDACEAE

Bryopsis plumosa Kuetz.—Plentiful in quiet shallow waters, on sandy bottoms, along the coral reefs; fronds 2–6 in. long, often highly pinnatifid.

CAULERPACEAE

Caulerpa pinnata (L.) Web.—Collected at Laysan Island.

C. racemosa var. *laetevirens* Web.—Collected at Laysan; there are several varieties; the species is known from the Red Sea.

C. laxifolia (Vahl.) Agh.—Plentiful along the leeward coral reefs in shallow waters and tidal pools, resembling a miniature *Lycopodium;* occurs throughout the Pacific and Indian oceans.

CODIACEAE

Halimeda tuna (Ell. and Sol.) Lam.—Abundant in the shallow waters along the coral reefs; a cosmopolitan species, and an important member of the reef-building series of algae.

H. opuntia (L.) Lam.—Has been collected at various points along the reefs and also at Laysan; a cosmopolitan species, with many varieties and forms. The reef-building powers of *Halimeda* and its associates have undoubtedly been underestimated in the past.

Codium adhaerens (Cabr.) Agh.—Thallus crustaceous, forming a sheet on the substratum, periphery excrescent; cosmopolitan.

C. tomentosum (Huds.) Stackh.—This and the preceding are called *limu aala-ula* by the natives; plentiful in shallow reef waters; thallus cylindric, elongate, dark green; cosmopolitan.

C. Muelleri Kuetz.—Known to the natives as *limu aala-ula;* on the island of Hawaii as *limu wawae-iole* and *limu wawae-moa;* it inhabits shallow coastal waters; often on exposed rocks in the surf, or on the outer margins of the reefs. The species of *Codium* all have stout holdfasts, and require a knife or chisel to collect them.

VALONIACEAE

Valonia aegagrophila (Roth) Agh.—Thallus irregularly tubular; cosmopolitan in all warm seas.

V. confervoides Harv.—Cosmopolitan in all warm seas; common in Hawaiian waters.

V. utricularis Agh.—Called *limu li-puu-puu* by the natives, and used by them for food; these species all live along the coral reefs, and are important fish food.

Dictyosphaeria favulosa (Agh.) Dcne.—Common along the reefs and coasts in shallow waters; also collected at Laysan.

Microdictyon umbilicatum (Velley) Zanard.—Leaflike, netted thalli; fairly common in pools and shallows along the reefs; a cosmopolitan species in all warm seas.

PITHOPHORACEAE

Pithophora affinis Nordst.—Native name *limu pala-wai* or *li-pala wai;* used for food; known only from the Hawaiian Islands.

CHARACEAE

Nitella hawaiensis Nordst.—In streams, brackish ditches, and pools.

Chara coronata var. *leptosperma* forma *oahuensis* (Meyen) A. Br.—In ditches and pools.

C. gymnopus var. *armata* (Meyen) Nordst.—On all the islands, in ditches, shallow pools, etc.

ZYGNEMACEAE

Mougeotia capucina (Bory) Agh.—Dark violaceous, in streams and pools; cosmopolitan, from Scotland to New Zealand.

Zygnema spontaneum Nordst.—In ditches, taro patches, rice fields, etc.; known only from the Hawaiian Islands.

Spirogyra is represented in the Hawaiian Islands by a number of species, abundant in streams and pools, both on the lowland and in the mountains; a number of them are used by the natives as food, and are called collectively *limu pala-wai.*

DESMIDIACEAE

The desmids are represented in the Hawaiian flora by the following known forms; there are undoubtedly very many forms as yet undescribed:

Desmidium aptogonium var. acutius Nordst., Gymnozyga moniliformis Ehrenb., Gonatozygon Ralfsii De Bary, Cylindrocystis Brebissonii Menegh., Closterium didymotocum var. multinucleatum Nordst., C. praelongum Breb., C. Pritchardianum Archer, C. lineatum var. sandvicense Nordst., C. dianae Ehrenb., C. parvulum Naeg., C. moniliferum (Bory) Ehrenb., C. setaceum Ehrenb., Penium lamellosum Breb., P. navicula Breb., Tetmemorus granulatus forma minor Nordst., T. levis var. continuus Nordst., Disphinctium palangula (Breb.) Hansg., D. subglobosum (Nordst.) DeToni, D. connatum (Breb.) De Bary, D. annulatum Naeg., D. speciosum var. simplex Nordst., Pleurotaenium trabecula (Ehrenb.) Naeg., P. Ehrenbergii (Ralfs) Delp., P. indicum (Gren.) Lund., P. nodulosum (Breb.) De Bary, Xanthidium armatum var. fissum Nordst., Cosmarium granatum var. subgranatum Nordst., C. Meneghini Breb., C. crenatum Ralfs, C. holmiense Lund., C. parvulum Breb. forma spetbergensis Nordst., C. sulcatum Nordst., C. depauperatum Nordst., C. anisochondrum Nordst., Arthrodesmus octocornis forma havaiensis Nordst., Euastrum binale (Turp.) Ralfs, E. ansatum Lund., E. sinuosum Lenorm., Micrasterias truncata (Corda) Breb., M. adscendens Nordst., Staurastrum subtile Nordst., S. spongiosum var. Griffithianum (Naeg.) Lagerh., S. subscabrum Nordst., S. muticum Breb., S. monticulosum var. duplex Nordst., S. margaritaceum Ehrenb., S. tenuissimum West.

This gives a total of 15 genera and 47 known species.

FLAGELLATAE

The following flagellates have been collected in ditches, taro patches, rice fields, fishponds, and other quiet, shallow waters:

Salpincoeca pyxidium S.K., Dinobryon sertularia Ehrenb., Euglena spirogyra Ehrenb., Phacus pyrum (Ehrenb.) Stein., P. pleuronectes Nitzsch., Trachelomonas volvocina Ehrenb. var. minuta Lemm., T. oblonga Lemm. var. truncata Lemm., T. hispida (Perty) Stein.

SILICOFLAGELLATAE

Several species have been taken in plankton between Hawaii and Laysan, as follows:

Dictyocha fibula var. messanensis (Haeckel) Lemm., var. stapedia (Haeckel) Lemm., Distephanus speculum (Ehrenb.) Haeckel.

PERIDINIALES

A considerable number of forms in this group have been taken in plankton between Hawaii and Laysan:

Pyrocystis fusiformis Wyv., P. pseudonoctulica Wyv., P. lunula Schuett., Hemidinium nasatum Stein., Pyrophacus horologium Stein., Ceratium candelabrum (Ehrenb.) Stein., C. furca (Ehrenb.) Clap. and Lachm., C. fusus (Ehrenb.) Duj., var. concavum Gourr., var. extensum Gourr., C. gibberum Gourr., var. contortum Gourr., C. gravidum Gourr., C. lineatum Ehrenb., C. tripos (Mueller) Nitzsch., var. arcticum (Ehrenb.) Cleve., var. arcuatum Gourr., var. horridum Cleve., var. macroceros (Ehrenb.) Clap. and Lachm., Gonyaulax polyedra Stein., G. polygramme Stein., Goniodoma armatum (Schuett.) Schmidt., Diplopsalis lenticula Bergh., Peridinium divergens Ehrenb., var. depressum (Bail.) Cleve., var. rhomboideum Lemm., P. inconspicuum Lemm., Oxytoxum Schauinslandii Lemm., Ceratocorys horrida Stein., var. longicornis Lemm., Phalacroma mitra Schuett., Amphisolenia palmata Stein., A. Schauinslandii Lemm., Histioneis quadrata (Schuett.) Lemm., H. Steinii (Schuett.) Lemm.

BACILLARIALES

The diatons are represented by a large number of forms; like the desmids, the group is very incompletely known in tropical waters.

Melosira Juergensii Agh., Gallionella nummuloides (Dill) Bory, Paralia sulcuta (Ehrenb.) Cleve., Hyalodiscus subtilis Bail., H. scoticus (Kuetz.) Grun., Sceletonema costatum (Grev.) Cleve., Cyclotella striata (Kuetz.) Grun., Coscinodiscus excentricus Ehrenb., C. dimorphus Castr., Archnoidiscus ornatus Ehrenb., Asteropampra marylandica Ehrenb., A. rotula Grev., Aulacodiscus orientalis Grev., Pyrgodiscus calyciflos. Temp. and Brun., Actinocyclus ornatus Rattr., A. Ralfsii (W.Sm.) Ralfs, A. splendens Rattr., A. Ehrenbergii Ralfs, A. subtilis (Greg.) Ralfs, Guinardia elongata Lemm., Rhizosolenia semispina Hensen., R. setigera Brightw., R. styliformis Brightw., R. temperi var. acuminata Perag., Bacteriastrum varians Lauder., Chaetoceros diversum var. tenue Cleve., C. laciniosum Schuett., C. peruvianum Brightw., Climacodium Jacobi Cleve., Triceratium arcticum Brightw., T. dubium Brightw., T. zonatula Grev., T. punctatum Brightw., T. Shadboldtianum var. robustum Lemm., Biddulphia pulchella Gray, B. reticulata Roper, B. imperialis Walker, Isthmia nervosa Kuetz., Isthmiella enervis (Ehrenb.) Cleve., Hemiaulus Hauckii Grun., H. delicatus Lemm., Terpisnoe musica Ehrenb., T. australis Ehrenb., Rhabdomena adriaticum Kuetz., R. robustum Grun., Tabellaria platystoma Ehrenb., T. rhabdostoma Ehrenb., Climacosira mirifica (W.Sm.) Grun., Striatella deliculata (Kuetz.) Grun., Grammatophora marina (Lyngb.) Kuetz., var. communis Grun., var. macilenta W.Sm., G. havaiensis Mereschk., G. angulosa Ehrenb.,

var. hamulifera (Kuetz.) Grun., Gephyria media Arnott, Opephora pacifica (Grun.) Petit., Licmomorpha flabellata (Carm.) Agh., L. remulus Grun., L. Ehrenbergii var. tenuistriata Mereschk., L. dubia Grun., L. Grunowii var. elongata Mereschk., L. Juergensii Agh., Climacosphenis moniligera Ehrenb., C. elongata Mereschk., Fragilaria capucina Desmaz., F. lamella Ehrenb., Rhaphoneis setaces Ehrenb., Synedra ulna var. splendens (Kuetz.) Brun., S. acus Kuetz., S. radians Kuetz., S. pulchella (Ralfs) Kuetz., S. affinis Kuetz., var. sandwicensis Grun., Ardissonia fulgens (Grev.) Grun., A. superba (Kuetz.) Grun., A. robusta (Ralfs) DeToni, Toxarium undulatum Bail., T. semilunare Lemm., T. Hennedyanum (Greg.) Grun., T. rostratum Hantz., Asterionella formosa Hass., A. notata. Grun., Eunotia pectinalis (Kuetz.) Rabenh., Acthnanthes glabrata (Grun.) Cleve., A. lanceolatum Breb., A. brevipes var. angustata Grev., var. pennaeformis Grev., Campyloneis Grevellei W.Sm., var. typica Cleve., Cocconeis pellucida Hantzsch., C. pseudomarginata Greg., var. intermedia Grun., C. heteroidea Hantzsch., var. sigmoides Grun., Caloneis liber var. linearis Grun., var. genuina forma tenuistriata Cleve., C. formosa Greg., Diploneis papula A.S., D. splendida Greg., D. Schmidtii Cleve., D. Weistlogii A.S., D. notabilis Grev., D. vacillans A.S., D. nitescens Greg., D. crabo var. multicostata Grun., var. minuta Cleve., Navicula cuspidata var. ambigua Ehrenb., N. pupula Kuetz., N. confervacea Kuetz., N. anceps var. obtusa Grun., N. cryptocephala Kuetz., N. rhyncocephala Kuetz., var. amphiceros Kuetz., N. consors A.S., N. cancellata var. Gregorii Ralfs, N. Zostereti Grun., N. brasiliensis Grun., N. concilians Cleve., N. Hennedyi var. tahitensis Cleve., Trachyneis aspera Ehrenb., var. pulchella W.Sm., T. antillarum var. Mereschk Cleve., T. velata A.S., Pinnularia appendiculata Agh., P. interrupta forma stauroneiformis (V.H.) Cleve., P. divergens W.Sm., P. borealis Ehrenb., P. stauroptera var. interrupta Cleve., P. acrosphaeria forma maxima Cleve., P. major Kuetz., P. viridis Nitzsch., Pleorosigma balticum (Ehrenb.) W.Sm., P. formosum W.Sm., P. rigidum W.Sm., P. angulatum W.Sm., Tropidoneis lepidoptera var. samoensis Grun., Mastogloia decussata Grun., M. fimbriata Brightw., M. minuta Grev., M. exigua Lewis, M. Goesii Cleve., M. citrus Cleve., M. pumila Grun., M. quinquecostata var. concinna A.S., M. electa A.S., Gomphonema parvulum Kuetz., G. gracile var. dichotomum W.S., G. lanceolatum Ehrenb., G. subclavatum Grun., G. olivaceum var. tenellum Kuetz., Rhiocosphenia curvata (Kuetz.) Grun., Amphora ovalis (Breb.) Kuetz., var. pediculus (Kuetz.) V.H., A. coffaeiformis Agh., A. lineolata Ehrenb., A. angusta var. eblongella Grun., Rhopalodia gibba (Ehrenb.) O.M., R. musculus (Kuetz.) O. Mueller, R. gibberula var. minuens O. Mueller, var. Vanheurckii O. Mueller, var. minuta O. Mueller, Nitzschia panduriformis Greg., var. minor Grun., N. subcostata Grun., N. Janischii Grun., N. angularis W.Sm., N. sigmoidea (Nit.) W.Sm., N. vermicularis (Kuetz.) Hant., N. sigma (Kuetz.) W.Sm., var. intercedens Grun., var. rigidula Grun., var. curvula (Ehrenb.) Grun., N. obtusa var. nana Grun., N. linearis (Agh.) W.Sm., N. palea (Kuetz.) W.Sm., N. ventricosa Kitton, N. lorenziana var. major Grun.,

N. curvirostris Cleve., var. closterium (Ehrenb.) V.H., N. acuclaris (Kuetz.) W.Sm., N. longissima (Breb.) Ralfs, N. pungens Grun., var. atlantica Cleve., Surirella fastuosa Ehrenb., S. anfractosa A.Sc., Podocystis adriatica Kuetz., Campylodiscus Grevillii Leud.-Fortm., C. kittonianus Grun.

Phaeophyceae

ECTOCARPACEAE

Ectocarpus simpliciusculus var. *vitiensis* Asken.—Along the coasts; often on other algae, for example, *Turbinaria;* also collected at Laysan.

E. indicus Sonder.—Plentiful along the coasts, in shallow waters; called *limu aka-akoa* or *limu hulu-ilio* by the natives, and in common use by them as food.

E. paradoxus Mont.—Common along the coasts and reefs.

SPHACELARIACEAE

Sphacelaria tribuloides Menegh.—Common in shallow waters along the coast.

S. furcigera Kuetz.—Fairly abundant in pools and shallow waters along the reefs.

ENCOELIACEAE

Hydroclathrus cancellatus Bory.—Abundant in shallow waters along the coral reefs; forms a stiff, olive-brown, perforated cushion, several inches in diameter.

Asperococcus bulbosus Lam.—Frequent in quiet shallows along the coast.

FUCACEAE

Turbinaria ornata J. Agh.—Abundant along the outer margins of the reefs, where it is exposed to the full force of the surf; also in deeper offshore waters; often cast up on the beaches in great quantities after storms.

T. vulgaris J. Agh.—Habitat as for the preceding, but not so abundant.

Sargassum obtusifolium J. Agh.—Known only from the Hawaiian Islands.

S. polyphyllum J. Agh. and var. *fissifolium* Grun.—Known only from these islands.

S. densum Dickie.—Known only from leeward Oahu; Honolulu Harbor.

S. incisum Dickie.—Known only from leeward Oahu; Honolulu Harbor.

S. echinocarpum J. Agh.—Recorded only from Hawaii and Fiji.

S. cymosum Agh.—Widely distributed in the Pacific and Atlantic oceans.

The species of *Sargassum* are all known as *limu kala* by the natives, and are used for food. They are probably the most abundant and widely distributed of the larger algae in the Hawaiian Islands. They grow in the shallow waters along the reefs, on stones and submerged ledges, and on the reefs themselves. In many restricted localities, for example, the leeward shores of Oahu, Kauai, and Molokai, they are more abundant than any other seaweed. The native uses have been described by REED as follows:

> *Limu kala* is sometimes broken into small pieces and soaked in fresh water until it turns dark and soft, then stuffed into salmon before it is roasted, or it is chopped with fish heads and salt. It is sometimes ripened by putting in water with a few mollusks called *leho*, salted slightly, and allowed to stand for several days before eating. *Limu kala* is more often than any other limu eaten on the beach, without any preparation other than rinsing off the sand and breaking into convenient pieces for eating with raw fish or squid. It is also sometimes put into meat gravies or stews just as it is served.

DICTYOTACEAE

Stypopodium lobatum Kuetz.—Occurs in many parts of the Pacific and Atlantic; collected at Laysan; thallus at first decumbent, later ascending; flabellate, palmatifid or lobate, concentrically zoned.

Padina Commersonii Bory.—Frequent in shallow water within the lagoons, often on muddy bottom; widely distributed in the Pacific and Atlantic oceans.

P. Pavonia (L.) Gaill.—Abundant along the coral reefs, in pools and lagoons; often growing where the water is distinctly muddy and brackish; gregarious and forming extensive colonies; occurs in many parts of the Atlantic and Pacific; called *limu pepeiao.*

Haliseris plagiogramma Mont.—Foliose parts flat, costate, dichotomous; grows far out on the outer margins of the reefs, where the heavy surf breaks, also in rather deep water. It occurs in other tropical and subtropical waters of the Atlantic and Pacific, for example, West Indies and Australia. It usually can be gathered only by diving or swimming. It grows here and there in small quantities only, on all the islands. It is a choice delicacy among the natives, who call it *limu lipoa*. It is often pounded and mixed with other seaweeds to give them its peculiar, penetrating, spicy flavor and odor. It is frequently served with meats or put into the gravy or stews to give them a peppery flavor, of which the Hawaiians are very fond. All Hawaiians like the odor and flavor of this alga, especially with raw fish. It is considered particularly delicious with raw flying fish, if simply broken and salted slightly.

H. pardalis Harv.—A very rare species, occasionally washed ashore after storms; also occurs in Australian waters; fronds linear, dichotomous.

Dictyota acutiloba J. Agh. and var. *distorta* J. Agh.—Recorded only from the Hawaiian Islands.

D. sandvicensis (Sond.) Kuetz.—Fairly abundant; also found in Australian waters, Red Sea, and Indian Ocean.

D. spinulosa Harv.—Rare; in various parts of the North Pacific.

D. dichotoma (Huds.) Lamx.—Common; widely distributed in all oceans.

The species of *Dictyota* are all called *limu alani* by the Hawaiians, but are seldom used for food, as they possess a bitter flavor.

ARTHROCLADIACEAE

Chnoospora pannosa J. Agh.—Fronds in a dense caespitose tangle, blackish, 6–10 cm. high, much branched and interwoven; reported only from the Hawaiian Islands.

C. fastigiata pacifica J. Agh.—Called by the natives *limu wawahi-wa'a* or *limu kau-pau*, and used as food; occurs in various parts of the Pacific, and also along the Atlantic shores of South America; fronds caespitose with numerous dichotomously branching fastigiate branches, color dark olive.

Rhodophyceae

BANGIACEAE

Porphyra leucosticta Thuret.—This is the famous *limu lua'u* of the Hawaiians, a very highly prized delicacy. It appears in late winter or early spring after the heavy southerly storms, and lasts for only a few days. It is found only on exposed rocks constantly dashed by the waves, so it is difficult and dangerous to collect, especially as the alga is extremely slippery and has to be scraped forcibly from the rocks in small bunches while the collector clings to his support and avoids the heavy waves. REED states as follows:

> He must be sure-footed, quick, and a good swimmer, if he collect *limu luau*. . . . . It is prepared by washing in the usual way in fresh water. It is then salted a little and put into clear water, where it becomes slippery and colors the water a lovely violet color. Sometimes *opihi*, a kind of limpet, is put in with the limu and salt in water, and placed in bottles or jars. This is used as needed, for it keeps many weeks when placed in the weak brine with the limpets.
>
> *Limu luau* is considered a great delicacy in the few localities where it occurs, but it lasts so short a season, is so scarce, and so difficult to get that it is not very widely known. Only on northern Kauai, northern Maui, and northern Hawaii is it in use or in great favor, as it does not occur in other places, except a few scattered plants on Oahu and Molokai.

HELMINTHOCLADIACEAE

Liagora valida Harv.—Collected at Laysan; also occurs in the Atlantic and around Madagascar; often calcareous.

L. coarctata Zanard.—Collected at Laysan.

L. decussata Mont.—Called *limu pu-aki* by the natives, and considered edible; grows along the coral reefs in quiet shallow water, often in mud or sand or on small stones; fronds filiform, virgate-ramified, calcareous.

CHAETANGIACEAE

Galaxaura lapidescens (Soland) Lamx.—Fronds cylindric or compressed, subtubular, incrusted with lime; along the coral reefs in shallow waters; a common species in warm seas.

G. spongiosa Kuetz.—Habitat same as the preceding.

Scinaia furcellata (Turn.) Biv. and var. *undulata* (Mont.) J. Agh.—Fronds solitary or clustered, arising from a disklike base, several times dichotomous; cosmopolitan, with several varieties.

Actinotrichia rigida (Lamx.) Descne.—Widely distributed in the Pacific and Indian oceans, and in the Red Sea.

GELIDIACEAE

Gelidium attenuatum (*?*).—Name used by REED; not listed by DETONI; probably a synonym.

G. corneum (*?*).—Name used by REED; not listed by DETONI; probably a synonym.

G. felicinum Bory.—Occurs in the Pacific Ocean.

G. intricatum (Agh.) Kuetz.—Listed as occurring in Hawaiian waters; according to DETONI an obscure species.

G. latifolium Born.—Cosmopolitan; abundant in Atlantic and Adriatic; common in Hawaiian waters.

G. cartilagineum (L.) Gaill.—In the Pacific and Atlantic oceans.

G. pusillum (Stackh.) Le Jol.—A cosmopolitan species.

The species of *Gelidium* are all called *limu loloa*, sometimes *limu ekaha-kaha*, by the natives, and are extensively used for food. They grow on exposed black lava rocks, near the tide line, in rough water, where they are constantly washed by the surf. They have tenacious holdfasts, and require a knife or chisel for collecting. These algae are abundant along the rocky shores of Kauai, Oahu, and Molokai, and also occur in considerable quantities on the other islands. They produce a dark, viscid gelatine, strongly flavored, but suitable for glue manufacture. REED states that "our species of *Gelidium* are undoubtedly as gelatinous as the Japanese species, but they are not nearly so plentiful."

Wrangelia penicillata Agh.—This beautiful, delicate, olive green, fernlike species inhabits tidal pools along the reefs and rocky shores; cosmopolitan.

Pterocladia capillacea (Gmel.) Bornet.—Uncommon; used by the natives of Kauai and Maui, and known by them as *limu loloa;* occurs also in Mediterranean and Atlantic.

GIGARTINACEAE

Gigartina papillata (Agh.) J. Agh.—Frond flat, simple or apparently dichotomous, segments truncate-cuneate; recorded only from the Hawaiian Islands and the Golden Gate.

Gymnogongrus vermicularis americana J. Agh.—A cosmopolitan species.

G. disciplinaris (Bory) J. Agh.—Recorded from various parts of the Pacific.

These algae are generally called *limu ua-ua-loli* by the natives, but there are also a number of other native names: *limu ekaha-kaha*, *limu ko-ele-ele*, *limu awiki-wiki*, *limu nei*. They grow far out on the coral reefs, along the outer margin, where the surf is heavy. All have tough, strong holdfasts. They are most abundant on Maui and Molokai, and are rather scarce in Hawaii.

Abnfeltia concinna J. Agh.—Native name *limu aki-aki* or *limu eleau*. A succulent, brittle, reddish brown alga, abundant on partially submerged lava rocks along the coasts. It shows a preference for exposed black lava rocks, in rough water, where it receives the heavy surf. It occurs in large quantities in these habitats along the shores of Kauai, Oahu, and Hawaii, and is plentiful here and there in a few localities on the other islands. Sometimes it grows in quiet coves or behind lava ledges in less exposed places. This seaweed is relished by the natives and is commonly sold in the markets. Its air dry composition is, roughly, water 20 per cent, protein 5 per cent, starches, sugar, etc., 55 per cent, crude fiber 3 per cent, ash 15 per cent. In the fineness and clarity of its gelatine this alga is exceeded only by *Gracilaria coronopifolia*.

A. Durvillaei (Bory) J. Agh.—Recorded from various parts of the Pacific.

RHODOPHYLLIDACEAE

Eucheuma nudum J. Agh.—Frond terete, subcompressed, dichotomously branched; recorded only from the North Pacific.

SPHAEROCOCCACEAE

Sphaerococcus coronopifolius (Good. and Wood.) Agh.—Fronds dichotomously branched; fairly common; also occurs in many parts of the Pacific and Atlantic.

Gracilaria coronopifolia J. Agh.—This species is called *limu manauea*, and is extensively used for food by the Hawaiians. It grows in shallow water along the reefs, on sandy bottoms, and in stormy weather often drifts ashore in considerable quantities. It is plentiful along the low beaches of leeward Kauai, Oahu, and Molokai. Because of the less favorable coasts, it is not abundant on Maui, and less so on Hawaii. The season of greatest abundance is spring and early summer, although it is fairly plentiful throughout the year. It is one of the limus commonly offered for sale in the native fishmarkets. Its air dry composition is, roughly, water 12 per cent, protein 8 per cent, starches, sugars, etc., 58 per cent, crude fiber 3 per cent, and ash 17 per cent. It makes fine clear gelatine of excellent quality, and requires less cooking for its preparation than do the other algae.

G. confervoides (L.) Bory.—Widely distributed in all oceans; fronds long, terete, much branched; edible, but not common.

Hypnea nidifica. J. Agh.—Intricately caespitose, expanded; known from various parts of the Pacific Ocean.

H. armata (Mert.) J. Agh.—Elongate; corymbosely branched. This and the preceding species are known as *limu huna* and are among the most commonly eaten of the Hawaiian seaweeds. They are especially relished by the natives when boiled with octopus. They are abundant along the coral reefs, in shallow waters, and often drift ashore in considerable quantities. The species of *Hypnea* are common on Kauai, Oahu, and Molokai; scarce on Maui, and very rare on Hawaii. They are outranked by both *Gracilaria* and *Ahnfeltia* in the quality and quantity of their gelatine.

RHODOMENIACEAE

Plocamium sandvicense J. Agh.—Known only from the Hawaiian Islands, leeward shores of Oahu; fronds pinnately decompound, very beautiful.

Champia compressa Harv.—Fronds branched, tubular, nodose, purple, gelatinous, membranous; known to the Hawaiians as *limu o-olu;* common along the reefs, both in shallow water and farther out. Its distribution is very irregular. Also in the South Pacific and African waters.

Chylocladia rigens (Agh.) J. Agh.—Edible, called *limu akuila* or *limu kihe;* common in many parts of the Pacific.

DELESSERIACEAE

Martensia flabelliformis Harv.—Plentiful in shallow waters along the reefs; fronds flat, dichotomous, with eccentric subimbriate lobes; also recorded from Samoa.

BONNEMAISONIACEAE

Asparagopsis Sanfordiana Harv.—A very delicate plant, resembling a miniature pink conifer. It grows far out along the margins of the reefs, in the shallow waters where the surf breaks. It has a number of Hawaiian names, *limu kohu* being the most common. On Maui, Molokai, and Kauai it is often called *limu lipa-akai* or *limu lipehu*. REED states that it is always pounded well as it is being cleaned, to free it from adhering bits of coral, and also that the subsequent soaking may the more thoroughly remove the disagreeable bitter flavor. It is soaked 24 hours or more in fresh water, to remove the bitter iodine flavor. It is then salted ready to be served as a relish or salad with meats, fish, or poi, or it is mixed with other seaweeds and put into hot gravy and meat stews. *Limu kohu* has a pleasant, although slightly bitter, flavor. It is sold in the form of balls about the size of a large baseball; the price is usually 25 cents per ball; it is always in great demand. At Moloaa, on the island of Kauai, a crude kind of culture of *limu kohu* is carried on. The natives have cleared out all of the other seaweed from the reef, so that the *Asparagopsis* does not suffer from competition, and is here much finer and more luxuriant than at any other place.

RHODOMELACEAE

Laurencia nidifica J. Agh.—Reported only from the Hawaiian Islands.

L. papillosa (Forst.) Grev.—Abundant; widely distributed in all seas.

L. obtusa (Huds.) Lamx.—Frequent; a cosmopolitan species.

L. vaga Kuetz.—According to DETONI probably a form of *perforata*.

L. pinnatifida (Gmel.) Lam. and var. *osmunda* Lam.—Reported.

L. perforata Mont.—Frequent; also in the tropical Atlantic.

L. virgata (Agh.) J. Agh.—Rare; in Pacific and African waters.

The species of *Laurencia* are known to the Hawaiians by various names; *limu maneo-neo* for the shorter, coarser species, *limu li-pee-pee* for the finer, longer forms. *Limu lipee* is a contracted phrase; *limu li-puu-puu*, a name used locally in certain districts on Maui and Hawaii. The species of *Laurencia* grow in shallow waters along the reefs, either on sandy bottom, or in rocky places. They are frequently washed ashore in considerable quantities by high tides or stormy weather. The natives use all the species for food, and the prepared *limu* may be purchased in the fishmarkets.

Chondria tenuissima var. *intermedia* Grun.—Called *limu o-olu* by the natives, who use it for food; abundant on the broad, shallow, sandy bottomed inshore waters of Kauai, Oahu, and Molokai; easily gathered. It prefers quiet water and rarely grows in places exposed to the surf. Common in the fishmarkets.

Polysiphonia tongatensis Harv.—According to DeToni probably a synonym for *P. mollis*.

P. polyphysa Kuetz.—According to DeToni probably a synonym for *P. ferulacea*.

P. ferulacea Suhr.—Common; widely distributed in all oceans.

P. mollis Hook. and Harv.—Called *limu pu-alu* or *limu hawane* by the natives; it is not popular, and is seldom used as food.

Amansia glomerata Agh.—The beautiful dark red rosettes of this alga are common in deep shady pools and crevices in the coral reef; Hawaiian names are *limu li-pepe-iao* or *limu pepe-iao*, and the natives use it for food.

CERAMIACEAE

Griffithsia ovalis Harv. (?).—A very rare species; sometimes used for food on Maui and southern Hawaii; called *limu moo-puna*, *limu ka-lipoa*, and *limu au-pupu*.

Ceramium clavulatum Agh.—Known by a number of native names; *limu hulu-ilio*, *limu hulu*, and *limu hulu wawae-iole;* abundant in shallow waters, within the reefs, growing on sandy bottoms, and easily gathered.

C. Kuetzingianum Grun.—Fronds minute, thin, branched; epiphytic on other seaweeds; also occurs in the South Pacific.

GRATELOUPIACEAE

Halymenia formosa Harv.—Rare; native name *limu lepeahina;* fronds gelatinous, flat, stipitate, much branched; also occurs in the South Pacific.

Grateloupia filicina (Wulf.) Agh.—Abundant in shallow waters within the reef; on sandy bottom and on rocks. Known to the Hawaiians as *limu paka-ele-awa'a* or *limu hulu-hulu-waena;* the former name is used exclusively on Kauai, the latter on Hawaii; both names are used on the intermediate islands. This alga also occurs in many other seas.

SQUAMARIACEAE

Peyssonnelia rubra Descne.—In shallow waters along the reefs, in company with such algae as *Halimeda Opuntia;* adherent to the substratum; sometimes calcareous; in many other seas.

CORALLINACEAE

Mastophora tenuis Descne.—Reported only from the Hawaiian Islands.

Amphiroa fragilissima (L.) Lamx.—Collected at Laysan; also abundant in the Indian Ocean, and along the shores of Peru.

Corallina sandvicensis Reinbold.—Collected at Laysan; fronds 4–5 cm. high; known only from Laysan.

The coralline algae have not been worked up taxonomically; there are probably 15 or 20 species in addition to the preceding.

COLLEGE OF HAWAII
HONOLULU

CHEMICAL BASIS OF CORRELATION[1]

I. PRODUCTION OF EQUAL MASSES OF SHOOTS BY EQUAL MASSES OF SISTER LEAVES IN BRYOPHYLLUM CALYCINUM

JACQUES LOEB

(WITH EIGHTEEN FIGURES)

In this paper the term correlation will signify the inhibiting influence which the growing buds of a leaf of *Bryophyllum calycinum* have upon the growth of other buds of the same leaf. It is generally known that in a complex organism the growth in one organ of the complex may inhibit the growth in other organs of the same complex.

In former papers[2] the writer has shown that when in *Bryophyllum calycinum* one organ inhibits the growth of buds in another organ the inhibited organ contributes in some cases material to the growth in the inhibiting organ. It was known through the experiments of WAKKER and DEVRIES[3] that if a piece of stem is left attached to a leaf of *Bryophyllum* the stem will inhibit the growth of shoots in the notches of the leaf, while such shoots will grow if the leaf is entirely isolated from the stem. The writer was able to show that in such a case the leaf accelerates the growth of a shoot in the stem attached to the leaf. Thus figs. 1 and 2 are sister leaves, that is, leaves from the same node of a stem of *Bryophyllum*. Both are dipping with their tips in water.[4] Leaf 1, without a stem, has formed a shoot in 22 days, while the sister leaf in fig. 2 has formed no shoot, due to the inhibiting effect of the piece of stem attached to the leaf. The latter has accelerated the growth of the shoot in the piece of stem attached to the leaf, however, for a piece of stem of

[1] From the Laboratories of The Rockefeller Institute for Medical Research.

[2] LOEB, J., BOT. GAZ. **60**:249. 1915; **62**:203. 1916; Science **41**:704. 1915; The organism as a whole, p. 153. Putnam's Sons, New York. 1916.

[3] DEVRIES, H., Jahrb. Wiss. Bot. **22**:35. 1890–91.

[4] The result is the same when the leaves are suspended in moist air instead of dipping into water.

equal size without a leaf attached to it will in the same time form no shoot or only a very tiny shoot (fig. 3). The inference was drawn that the inhibiting effect of the stem upon the leaf in fig. 2 was due to the fact that the leaf furnished the material required for the growth of shoots to the stem instead of to its own notches. This takes place even when no shoot is formed in the stem; in that case the material furnished by the leaf is stored in or consumed by

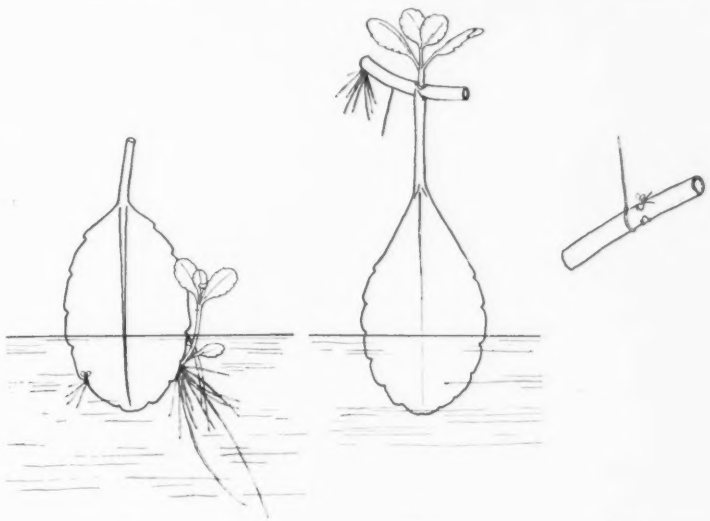

FIG. 1 FIG. 2 FIG. 3

FIGS. 1–3.—Figs. 1, 2, sister leaves; leaf of fig. 2 still attached to stem, showing stem inhibits shoot formation in leaf; fig. 2 shows inhibition is accompanied by accelerating effect of leaf upon growth of shoot from stem, since in a piece of stem, suspended in moist air, as in fig. 3, production of shoots is suppressed or retarded.

certain cells of the stem, as indicated, for example, by callus formation and by geotropic curvature.[5]

The same principle was shown to hold if stems without leaves are suspended in moist air. In such cases the two buds of the most apical node of a long piece of stem grow out (fig. 4), and it can be shown that the basal part of the stem whose buds are inhibited from growing furnishes to the growing buds at the apex

[5] LOEB, J., Science **46**:547. 1917.

the material required for their growth, for if we cut out short pieces with one node only (fig. 4, *a*, *b*, *c*, *d*), the growth of the shoots from the buds is retarded. This is not the only factor of inhibition in this case, since the writer has recently shown[6] that a growing bud, as well as a leaf, seems to send out inhibitory substances toward the base of the stem which prevent the buds in the stem, situated more basally, from growing out. This factor of inhibition will not be considered in this paper.

We shall try to show in this paper that the quantity of material available for the formation of shoots is definite and limited, and that inhibition may result from the retention or utilization of part of this material by the inhibiting organ. A preliminary note of these results has already been published.[7]

Each notch of a leaf of *Bryophyllum calycinum* can give rise to a shoot when the leaf is cut off from the stem and suspended in moist air, but as a rule only a few of these notches will grow into new plants. When we cut the leaf into as many pieces as there are notches, practically each piece (very small ones only excepted) will give rise to a shoot. Figs. 5 and 6 are sister leaves. Leaf 5 is cut into as many pieces as there are notches, while leaf 6 is left intact. Both were kept on moist filter paper. Leaf 5 has given rise to a new shoot in practically each notch, while leaf 6 has formed only 4 shoots. We assume that in the latter leaf the shoots which

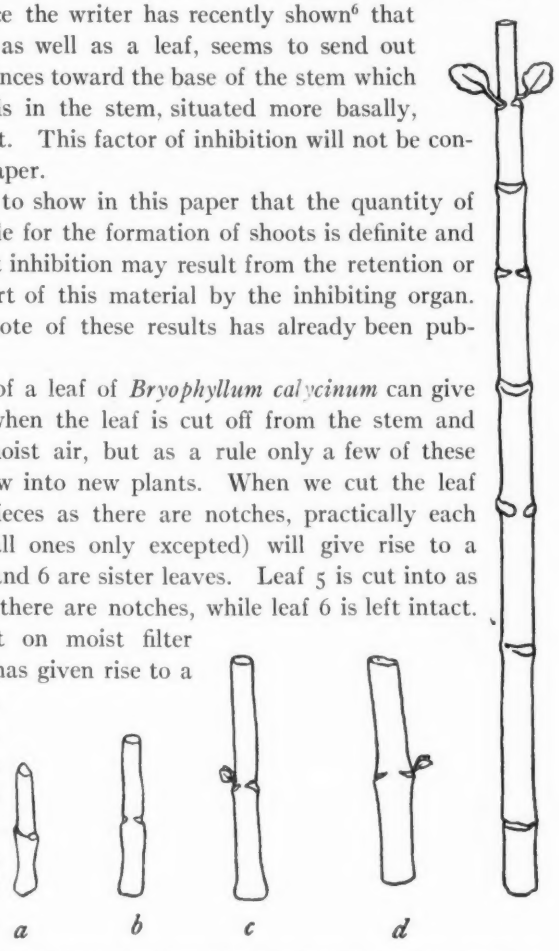

FIG. 4.—Shows that inhibited basal part of the long stem accelerates growth of the two apical buds, since in pieces with one node only (*a*, *b*, *c*, *d*) the buds do not grow at all, or much more slowly.

[6] LOEB, J., Science **46**:547. 1917. [7] *Ibid.*, **45**:436. 1917.

grow out first inhibit the growth in the other notches. (No part of the leaf of *Bryophyllum calycinum* except the notches is able to give rise to shoots or roots. The formation of roots will be omitted from consideration in this paper in order to simplify the discussion.) Our contention is that this inhibition in leaf 6 is due to the absorption of all the material available for shoot formation by the 4 notches that happened to grow out first, thus depriving the other notches of the material needed for the growth of shoots. By comparing figs. 5 and 6 it will be noticed that 3 of the shoots which leaf 6 produced are considerably larger than the individual shoots

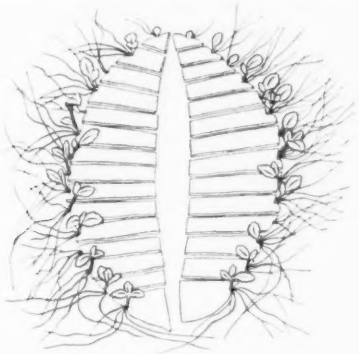

FIG. 5

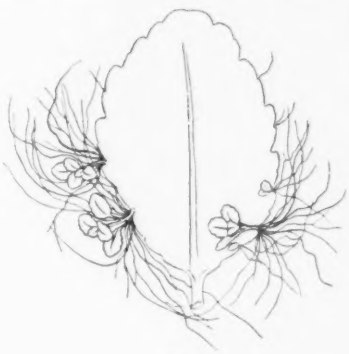

FIG. 6

FIGS. 5, 6.—Sister leaves: fig. 5, leaf cut into as many pieces as notches; almost every notch forms a shoot; fig. 6, leaf intact, only 4 shoots formed, 3 being considerably larger than those shown in fig. 5, thus indicating tendency of both leaves to produce equal masses of shoots, although number of shoots may vary considerably.

of leaf 5, and this suggests the possibility that the isolation of a piece with one notch simply prevents the material needed for the growth of the notch being taken away by some of the other notches which by chance start growing a little earlier.

In order to prove this we must be able to show that if we isolate two sister leaves (which are of equal size, age, and history) and keep them under equal conditions, they will produce in equal times approximately equal masses of shoots. It is necessary, of course, that both leaves are healthy and not yet beginning to etiolize, and that they should not do so during the course of the experiment.

It is necessary also that the experiment be continued long enough (that is, a month or longer at about 23°C.) to allow the shoots to reach a sufficiently large size, since if the shoots are too small the error in measuring their masses prevents exact results. On the other hand, the experiment must not last too long, for if the shoots become too large they produce themselves too considerable a share of the material needed for their own growth. The leaves were generally kept on wet filter paper in flat dishes with a loose glass cover. One of the greatest sources of error or variation in the results was probably the differences in the absorption of water by the roots of different leaves or pieces of leaves. Furthermore, light is an important factor in determining the masses of shoots produced, and when leaves are suspended in an aquarium and able to shade each other, inequality of illumination of sister leaves also forms a source of error. The new shoots can be cut off from the leaf comparatively neatly, although slight variations or errors are unavoidable in this operation. The shoots were freed from water droplets on their surface and weighed fresh, on the assumption that the dry weight under the conditions of the experiment is a fairly constant fraction of the fresh weight, which has been found to be approximately correct. The leaves were usually but not always weighed without their petioles.

TABLE I

Sister leaves	Number of shoots produced from leaf	Mgm. of shoots produced in 33 days
I. Leaf 1.....	3	350
Leaf 2.....	3	345
II. Leaf 1.....	1	290
Leaf 2.....	2	306
III. Leaf 1.....	2	375
Leaf 2.....	4	385
IV. Leaf 1.....	5	594
Leaf 2.....	4	607
V. Leaf 1.....	4	457
Leaf 2.....	5	455

Table I gives the weight of the shoots produced by 5 pairs of sister leaves in 33 days (February 15—March 20). The two sister

leaves are always designated as 1 and 2. It is found that each of two sister leaves which were of equal size produced almost identical masses of shoots in the same period of time and under equal conditions, although the number of shoots by two sister leaves differed.

Table II gives another experiment of the same kind. The two sister leaves produce in each case almost identical masses of shoots

TABLE II

MARCH 29—APRIL 20, 1917

Sister leaves		Number of shoots	Weight of shoots in gm.	Weight of leaves in gm.	Mgm. of shoots produced per gm. of leaf
I.	Leaf 1	7	0.2560	2.3030	111
	Leaf 2	9	0.2455	2.2555	109
II.	Leaf 1	5	0.1920	1.783	108
	Leaf 2	4	0.2075	1.8735	111
III.	Leaf 1	5	0.2005	2.262	89
	Leaf 2	3	0.1605	1.982	81
IV.	Leaf 1	5	0.1910	1.668	114
	Leaf 2	4	0.1570	1.402	112
V.	Leaf 1	4	0.3205	2.5125	128
	Leaf 2	7	0.3760	3.0770	122
VI.*	Leaf 1	3	0.1790	2.191	82 etiolized
	Leaf 2	?	0.0595	1.597	37 leaves
VII.	Leaf 1	6	0.2355	2.6405	89
	Leaf 2	4	0.216	2.288	94
VIII.	Leaf 1	2	0.109	1.326	82
	Leaf 2	4	0.132	1.505	88
IX.	Leaf 1	3	0.172	1.927	89
	Leaf 2	5	0.187	2.093	89
Average	Leaves 1	.....	1.675	16.430	102
	Leaves 2	.....	1.682	16.476	102

* Pair VI is not included in the average.

in the same time, although the number of shoots varies quite often. The shoots produced by the two leaves of the sixth pair differ considerably, but those two leaves were etiolized. They were excluded from the calculation of the average shoot production, which is exactly the same for each set of leaves, namely 102 mgm. of shoots for 1 gm. of leaf.

Tables III and IV show a slightly greater variation than tables I and II, owing to the inevitable errors in such experiments (errors in cutting off and ascertaining the weight of the small shoots, errors in evaporation, differences in the condition of the two sister leaves,

TABLE III

APRIL 11—MAY 10, 1917

Sister leaves	Number of shoots	Weight of shoots in gm.	Weight of leaves in gm.	Mgm. of shoots produced per gm. of leaf
I. Leaf 1	2	0.180	1.655	109
Leaf 2	1	0.201	1.590	126
II. Leaf 1	2	0.115	1.050	109
Leaf 2	2	0.166	1.505	110
III. Leaf 1	3	0.155	1.081	143
Leaf 2	2	0.140	1.098	127
IV. Leaf 1	3	0.123	1.158	106
Leaf 2	3	0.126	1.245	101
V. Leaf 1	2	0.110	1.038	106
Leaf 2	2	0.089	0.995	90
VI. Leaf 1	2	0.183	1.646	111
Leaf 2	2	0.153	1.383	111
VII. Leaf 1	3	0.231	1.617	143
Leaf 2	3	0.178	1.463	122
VIII. Leaf 1	4	0.220	1.547	142
Leaf 2	2	0.146	1.172	125
IX. Leaf 1	3	0.119	1.230	97
Leaf 2	3	0.149	1.410	106
Average Leaves 1	.....	1.436	12.022	119
Leaves 2	.....	1.348	11.861	114

and in the external conditions of moisture and light, and others). The fact that these errors are accidental is proved by the proximity of the average shoot production in each set of leaves, which is 119 and 114 mgm. of shoots per gm. of leaf in table III, and 106 and 100 mgm. in table IV.

We may make the following statement, therefore: *Two healthy, isolated sister leaves of equal mass will produce in equal times and under equal conditions approximately equal masses of shoots, although*

the number of shoots in the two leaves may differ. The variations in the results lie within the limits of the unavoidable errors of the experiments.

TABLE IV

INTACT SISTER LEAVES; MARCH 20—APRIL 18, 1917

Sister leaves		Number of shoots	Weight of shoots in gm.	Weight of leaves in gm.	Mgm. of shoots produced per gm. of leaf in 29 days
I.	Leaf 1	3	0.127	1.310	97
	Leaf 2	2	0.128	1.170	109
II.	Leaf 1	2	0.150	1.595	94
	Leaf 2	3	0.1325	1.323	100
III.	Leaf 1	4	0.2085	1.9175	109
	Leaf 2	2	0.1575	1.722	91
IV.	Leaf 1	3	0.270	2.286	118
	Leaf 2	4	0.145	1.586	91
V.	Leaf 1	2	0.147	1.3385	110
	Leaf 2	5	0.2075	2.061	101
VI.	Leaf 1	4	0.211	1.9735	107
	Leaf 2	3	0.220	2.0275	107.5
VII.	Leaf 1	2	0.1065	0.9435	113
	Leaf 2	3	0.105	1.062	99
VIII.	Leaf 1	5	0.233	2.332	100
	Leaf 2	4	0.228	2.2595	101
Average	Leaves 1	.....	1.452	13.69	106
	Leaves 2	.....	1.322	13.21	100

It would follow that if we cut a leaf into two symmetrical halves each half should produce equal masses of shoots in the same time and under the same conditions. This is approximately correct, as table VI shows.

The experiment was repeated (table V), and we may confine ourselves to a statement of the average result. The two halves are designated as right and left, when facing the observer with their basal end and when lying on their lower side.

It is obvious, therefore, that if leaves are cut symmetrically, the two halves will produce in equal times and under equal conditions on the average exactly the same mass of shoots, even when the number of shoots in the two halves varies.

While in the preceding experiments the number of shoots produced in sister leaves was not identical, yet it seemed of interest to find out whether the law of the production of equal masses of shoots by equal masses of sister leaves was true also if the number

TABLE V

APRIL 12—MAY 15

	Number of shoots	Weight of shoots in gm.	Weight of leaves in gm.	Mgm. of shoots produced per gm. of leaf
20 left halves of leaves.....	33	2.916	19.307	151
20 right halves of leaves....	31	2.790	18.466	151

TABLE VI

SISTER LEAVES, EACH CUT INTO TWO SYMMETRICAL HALVES; APRIL 3—MAY 4

Sister leaves			Number of shoots	Weight of shoots in gm.	Weight of leaves in gm.	Mgm. of shoots produced per gm. of leaf
I.	Leaf 1	Left half....	2	0.188	0.936	203
		Right half...	2	0.183	0.959	191
	Leaf 2	Left half....	1	0.202	1.009	200
		Right half...	2	0.254	1.241	205
II.	Leaf 1	Left half....	1	0.057	0.427	133
		Right half...	2	0.053	0.398	133
	Leaf 2	Left half....	1	0.063	0.441	143
		Right half...	1	0.056	0.398	141
III.	Leaf 1	Left half....	1	0.120	0.820	146
		Right half...	3	0.111	0.758	146
	Leaf 2	Left half....	1	0.116	0.713	163
		Right half...	1	0.115	0.721	160
IV.	Leaf 1	Left half....	1	0.070	0.407	141
		Right half...	1	0.072	0.580	124
	Leaf 2	Left half....	2	0.073	0.595	122
		Right half...	1	0.068	0.522	130

of shoots produced in the two leaves differed considerably. For this purpose one leaf was cut into 4 pieces while its sister leaf remained intact. The whole leaves produced fewer shoots than the leaves cut into 4 pieces; nevertheless, the masses of shoots produced in the two sets of leaves remained the same. Thus 12

intact leaves produced 25 shoots, while their sister leaves cut into 4 pieces each produced 50 shoots. Yet the average weight of shoots produced per gm. of leaf was 156 mgm. for the intact leaves and

TABLE VII

SISTER LEAVES, ONE INTACT, THE OTHER CUT INTO FOUR PIECES; APRIL 18—MAY 18, 1917

Sister leaves		Number of shoots	Weight of shoots in gm.	Weight of leaves in gm.	Mgm. of shoots produced per gm. of leaf
I.	Leaf 1, intact	2	0.198	1.170	169
	Leaf 2, 4 pieces	4	0.2025	1.205	168
II.	Leaf 1, intact	2	0.216	1.596	135
	Leaf 2, 4 pieces	4	0.214	1.560	137
III.	Leaf 1, intact	1	0.305	1.925	158
	Leaf 2, 4 pieces	4	0.368	2.110	174
IV.	Leaf 1, intact	2	0.340	1.9015	177
	Leaf 2, 4 pieces	4	0.2035	1.475	179
V.	Leaf 1, intact	2	0.197	1.072	184
	Leaf 2, 4 pieces	4	0.200	1.227	163
VI.	Leaf 1, intact	3	0.265	1.743	152
	Leaf 2, 4 pieces	6	0.292	1.675	174
VII.	Leaf 1, intact	2	0.2415	1.741	138
	Leaf 2, 4 pieces	4	0.255	1.745	146
VIII.	Leaf 1, intact	1	0.105	1.260	155
	Leaf 2, 4 pieces	4	0.109	0.660	165
IX.	Leaf 1, intact	2	0.218	1.198	182
	Leaf 2, 4 pieces	4	0.209	1.110	188
X.	Leaf 1, intact	2	0.223	1.514	147
	Leaf 2, 4 pieces	4	0.180	1.280	140
XI.	Leaf 1, intact	4	0.258	1.820	142
	Leaf 2, 4 pieces	5	0.2015	1.818	144
XII.	Leaf 1, intact	2	0.227	1.498	151
	Leaf 2, 4 pieces	3	0.191	1.205	158
Average	Intact leaves	25	2.884	18.435	156
	Leaves cut into 4 pieces	50	2.747	17.070	161

161 mgm. for the leaves cut into 4 pieces, in spite of the difference in the number of shoots produced. Table VII gives the results in detail. These experiments again confirm the conclusion that equal

masses of sister leaves produce equal masses of shoots in equal time, even if the number of shoots in the two cases is in the ratio of 1:2.

In order to test further this law it seemed necessary to modify the experiment. For this purpose the mass of one of two sister leaves was reduced by cutting out a large piece from the center, leaving the edge intact (fig. 8), while the other leaf remained intact (fig. 7). If the law just expressed is correct, it should follow

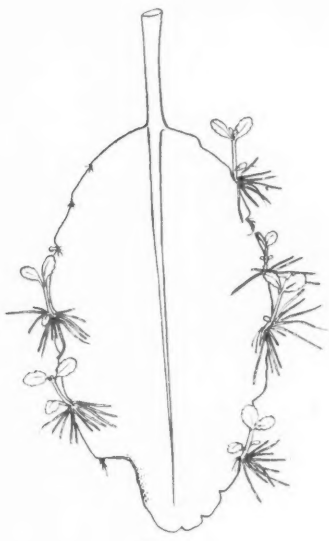

FIG. 7

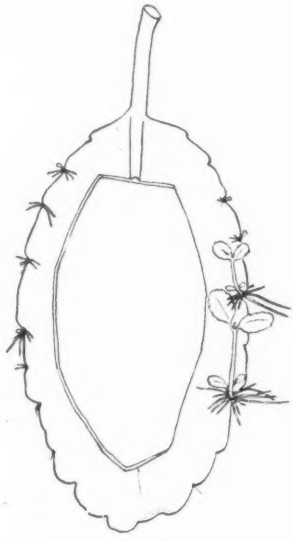

FIG. 8

FIGS. 7, 8.—Sister leaves suspended in moist air: fig. 7, leaf intact; fig. 8, leaf with mass reduced by cutting out large piece from center of leaf; mass of shoots produced smaller than that produced by intact leaf; drawn 23 days after beginning of experiment.

that the mass of shoots produced by such sister leaves (one set of which remained intact while the mass of the other set was reduced by cutting out pieces from the middle) would no longer be equal, but would differ in proportion to the mass of the two sets of leaves. This was found to be approximately true, as table VIII indicates.

Thus in experiment I (table VIII) the 5 intact leaves weighing 13.8 gm. produced in 37 days 1405 mgm. of shoots, while their 5

sister leaves, whose weight was reduced from approximately 13.8 gm. to 7.6 gm. (by cutting out pieces from the center of the leaf as indicated in fig. 8), produced in the same time and under the same condition 755 mgm. of shoots. While the proportion of the mass of the two sets of leaves was $\frac{7.6}{13.8}$, the proportion of the mass

TABLE VIII

Number of experiment	Sister leaves	Number of shoots	Weight of shoots in gm.	Weight of leaves in gm.	Mgm. of shoots produced per gm. of leaf
I.	Leaves dipping in water; duration of experiment 37 days	(*a*) 5 leaves, with center cut out	11	0.755	7.61	99
		(*b*) 5 sister leaves, intact	9	1.405	13.80	101
II.	Leaves dipping in water; duration of experiment 25 days	(*a*) 7 leaves, with center cut out	21	1.213	9.899	122
		(*b*) 7 sister leaves, intact	25	1.995	16.935	118
III.	Leaves dipping in water; duration of experiment 32 days	(*a*) 9 leaves, with center cut out	22	2.292	10.522	218
		(*b*) 9 sister leaves, intact	30	3.430	17.852	192
IV.	Leaves dipping in water; duration of experiment 27 days	(*a*) 12 leaves, with center cut out	33	2.175	11.245	194
		(*b*) 12 sister leaves, intact	33	2.761	19.395	142
V.	Leaves kept in moist air; duration of experiment 38 days	(*a*) 5 leaves, with center cut out	13	0.690	5.42	109
		(*b*) 5 sister leaves, intact	20	1.207	11.81	102

of the shoots produced was $\frac{755}{1405}$. These two quotients are almost identical. The same is true for experiments II, III, and V, while in IV there is a greater discrepancy. Experiments III and IV indicate that if there is such a discrepancy it seems to be in favor of the leaf reduced in size. Since light plays such an important rôle in the production of shoots the discrepancy may possibly be due to the accidental fact that the intact leaves shaded

each other more in these experiments than the leaves with their centers cut out.

FIG. 9.—Sister leaves: one cut into 4 pieces, other not subdivided, but all notches except one removed; from this notch a shoot is produced considerably larger than each of shoots produced from the 4 smaller pieces of other leaf; photographed 19 days after beginning of experiment.

The shoots produced by the whole leaves and by the leaves reduced in mass, therefore, were approximately in proportion with the masses of the two sets of leaves; or in other words, each set of sister leaves produced

approximately the same weight of shoots per gram of leaf in the same length of time.

When a leaf is isolated and put on moist filter paper or if it is suspended in moist air, as a rule more than one notch grows out into a shoot (fig. 6). This seems to indicate that the material available for shoot formation in one leaf does not all flow easily into one notch, so that we should expect that the material available in a leaf might be utilized more completely if the leaf were cut into several smaller pieces than if all the material had to go into one shoot only. This fact is evident from the following experiment.

In one leaf the whole edge (containing the notches) with the exception of one notch was removed (fig. 9). Such a leaf could form only one shoot. The sister leaf was cut into 4 pieces but the edges were left intact. These 4 pieces could form at least 4 shoots. Fig. 9 shows such a pair of sister leaves. It was to be expected that the total weight of the shoots formed by the 4 pieces would be approximately equal to that of the one shoot in the sister leaf, or exceed it slightly for the reason indicated. Table IX shows that 6 shoots produced in 6 whole leaves differed very little in weight from the 32 shoots produced by their 6 sister leaves, each of which was cut into 4 pieces, but that the difference was in favor of the leaves cut into 4 pieces. The latter produced per gram leaf 93 mgm. of shoots, the former 84 mgm. In a second set of experiments the difference was in the same direction, but a little larger, namely 98 mgm. and 74.5 mgm. (table IX). While these experiments confirm the law of equal production of shoots by equal masses of leaf, they also indicate that several shoots can consume the material available in one leaf more quickly than if only one shoot is present.

A second complication is encountered when small pieces containing one notch are cut out from a leaf (fig. 6). In this case it may happen that when the piece is too small the notch of the small piece may not form any shoot at all, or the growth may be materially delayed. This is intelligible on the assumption that if the quantity of material available falls below a certain minimum no shoot can grow out. Fig. 10 illustrates this statement. A large and a small piece were cut out from the same leaf, each piece containing one notch only, the notches in each set of two pieces originally being

symmetrical. The photograph was taken 36 days after the beginning of the experiment. It will be seen that the size of the shoot varies with the size of the piece, but that some of the smallest pieces have failed to form shoots. This fact is to be considered in experiments in which one leaf is left intact and the sister leaf cut into as many pieces as there are notches. In that case it may happen that the law of equal production of shoots by equal masses of leaves

TABLE IX

SISTER LEAVES: (*a*) WHOLE LEAF, BUT ALL NOTCHES WITH EXCEPTION OF ONE REMOVED; (*b*) CUT INTO 4 PIECES, BUT NO NOTCH REMOVED; APRIL 5—APRIL 25, 1917

Sister leaves		Number of shoots	Weight of shoots in gm.	Weight of leaves in gm.	Mgm. of shoots per 1 gm. of leaf
I.	(*a*) Whole leaf	1	0.1935	2.403	81
	(*b*) 4 pieces	6	0.206	2.267	91
II.	(*a*) Whole leaf	1	0.110	2.234	49
	(*b*) 4 pieces	6	0.105	2.431	43
III.	(*a*) Whole leaf	1	0.136	1.647	83
	(*b*) 4 pieces	5	0.185	2.083	89
IV.	(*a*) Whole leaf	1	0.196	1.8325	107
	(*b*) 4 pieces	7	0.2975	2.387	125
V.	(*a*) Whole leaf	1	0.201	2.035	99
	(*b*) 4 pieces	4	0.246	2.225	110
VI.	(*a*) Whole leaf	1	0.110	1.086	101
	(*b*) 4 pieces	4	0.154	1.4015	109
		Total number of shoots	Total weight of shoots	Total weight of leaves	Shoots per gm. of leaf; mgm.
Average	(*a*) Whole leaves	6	0.9465	11.237	84
	(*b*) Cut leaves	32	1.103	12.794	93

may not hold strictly, for two reasons: (1) some of the small pieces may not form any shoot at all or form it only too late; (2) a complication may vitiate the result in the opposite direction, namely, that the shoots formed by small pieces can use the material available for shoot formation more readily than the shoots in the whole leaves. Table XI gives the results of such an experiment on 3 pairs of sister leaves, one leaf remaining intact or cut into two symmetrical halves, while the other was cut into as many pieces as there were notches.

In spite of the enormous difference in the number of shoots in both cases, the weight of shoots produced by one gram leaf in a given time was not very different, the average being 143 mgm. of shoots in one set and 150 mgm. in the other set per gram of leaf.

The law of equal production of shoots by equal masses of leaves explains why the shoots growing out from the notches of a leaf grow the more rapidly the smaller their number. It does not explain

TABLE X

SISTER LEAVES: (*a*) WHOLE LEAF, BUT ALL NOTCHES WITH EXCEPTION OF ONE REMOVED; (*b*) CUT INTO 4 PIECES, BUT NO NOTCH REMOVED; APRIL 4—APRIL 25, 1917

Sister leaves		Number of shoots	Weight of shoots in gm.	Weight of leaves in gm.	Mgm. of shoots per 1 gm. of leaf
I.	(*a*) Whole leaf	1	0.201	2.202	90.5
	(*b*) 4 pieces	6	0.316	2.542	124
II.	(*a*) Whole leaf	1	0.144	2.0325	71
	(*b*) 4 pieces	4	0.2335	2.3235	100.5
III.	(*a*) Whole leaf	1	0.162	1.832	88
	(*b*) 4 pieces	4	0.179	1.950	92
IV.	(*a*) Whole leaf	1	0.147	2.152	68
	(*b*) 4 pieces	4	0.256	2.5145	102
V.	(*a*) Whole leaf	1	0.150	2.710	55
	(*b*) 4 pieces	4	0.191	2.067	72
VI.	(*a*) Whole leaf	1	0.084	0.986	85
	(*b*) 4 pieces	4	0.111	1.107	100
		Total number of shoots	Total weight of shoots	Total weight of leaves	Shoots per gm. of leaf; mgm.
Average	(*a*) Whole leaves.	6	0.8889	11.915	74.5
	(*b*) Cut leaves ...	26	1.2875	13.104	98

how it happens that in an isolated leaf not all the notches grow out into shoots.

When we cut off a leaf and suspend it in moist air (the air not being completely saturated with water vapor), after some time most of the notches form roots, as the leaf in fig. 11 indicates, which was drawn 18 days after the beginning of the experiment. If there are any notches which do not form roots, they are usually found at the apex and at the base of the leaf (fig. 11). After the roots are

formed, shoots begin to grow out of the notches, and now a remarkable change occurs. Fig. 12 shows the same leaf as fig. 11, 10 days

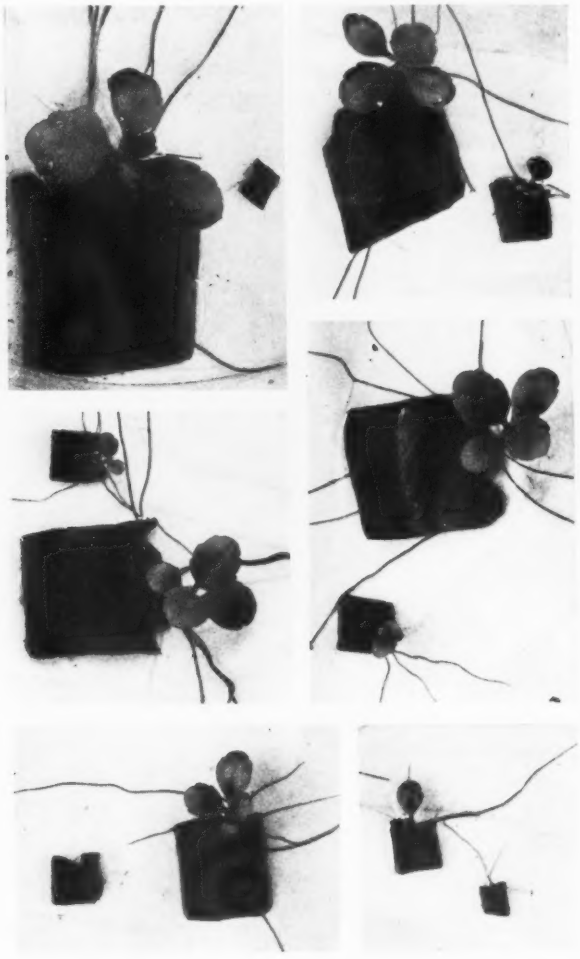

FIG. 10.—Large and very small pieces, each with one notch cut from one leaf; smallest pieces have not yet formed shoots (in 4 weeks); parallelism between size of leaf and size of shoot obvious.

later. Two of the shoots in the notches in the middle of the leaf have grown into shoots, and in these notches the roots have continued to grow; while the roots formed in the other notches have shriveled up and no new shoots have grown out.

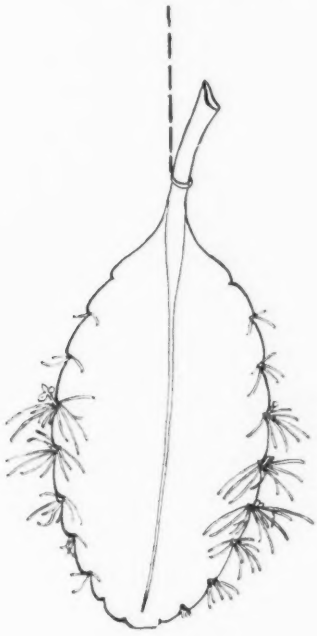

FIG. 11

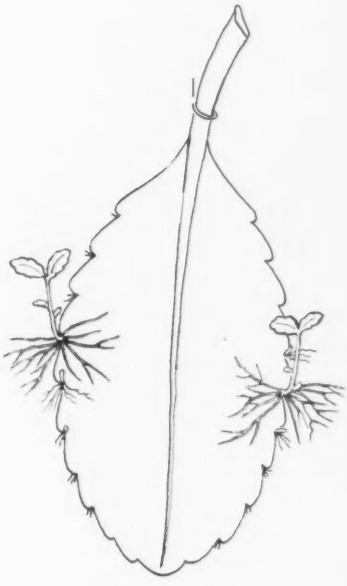

FIG. 12

FIGS. 11, 12.—Same leaf suspended in moist air, in fig. 11 after 18 days, in fig. 12 after 28 days; at first all notches in middle of leaf form roots and in some of them shoots begin to develop (fig. 11); later (fig. 12) only two of these shoots in middle of leaf grow, while roots in other notches not only ceased to grow but are shriveled up; proves inhibiting effect of most rapidly growing notches on others.

From this observation, which is typical and which has been verified many times, we are inclined to draw the following conclusion. As long as the leaf is part of the normal plant, its sap flows into the stem of the plant and the notches cannot grow out. When the leaf is separated from the plant and suspended in moist air, this flow ceases and the material carried in the form of sap

remains in the leaf and becomes available for the notches. As a consequence the notches in the leaf begin to grow out. The chances for growth are apparently not equal for all the notches of a leaf suspended in moist air, but are as a rule better for those in the middle of the leaf, where the leaf is thicker and where probably more sap is available. The roots grow out before the shoots begin

TABLE XI

FEBRUARY 15—MARCH 20, 1917

Sister leaves		Number of shoots	Weight of shoots in gm.	Weight of leaves in gm.	Mgm. of shoots per gm. of leaf
I.	(*a*) 2 halves	3	0.316	1.866	170
	(*b*) 16 pieces	14	0.345	1.727	200
II.	(*a*) Whole leaf	4	0.490	2.061	233
	(*b*) 14 pieces	14	0.312	1.810	172
III.	(*a*) Whole leaf	2	0.450	4.465	100
	(*b*) 17 pieces	15	0.300	3.17	95
Averages	Whole or half leaves	9	1.256	8.392	150
	Leaves cut into small pieces	43	0.957	6.71	143

to grow. Those shoots which happen to grow out first now become a center of attraction for all the material available for growth in the leaf, and they thereby inhibit not only the growth in most of the other notches but actually cause the roots formed in other notches to dry out again, as a comparison of fig. 12 with fig. 11 shows. We cannot yet tell how it happens that the more rapidly growing leaf attracts the sap to itself.

We have mentioned that as a rule the notches which will grow out first are not the ones at the apical or basal ends, but in the middle of the leaf, where the leaf is thickest and where apparently more sap is available. That it is possibly only the quantity of water which decides the initiation of growth[8] is suggested by the fact that a leaf, like the one in fig. 12, which, when suspended in moist air forms no shoots in the apical notches, can be caused at

[8] This refers only to the initial step of starting the growth in a dormant bud; its actual growth, of course, depends upon the supply of sugar, amino acids, salts, and other solutes from the leaf.

any time to form new shoots in these notches if we let the apex dip into water. As soon as this happens these notches will form shoots and these shoots will soon equal or exceed in size the old stems, and in turn may now inhibit the growth of the latter.

The leaf in fig. 12 was drawn on January 30. On February 7 its apex was suspended in water and soon new shoots formed in the apical notches (figs. 13, 14). Fig. 13 was drawn 9 days, and fig. 14,

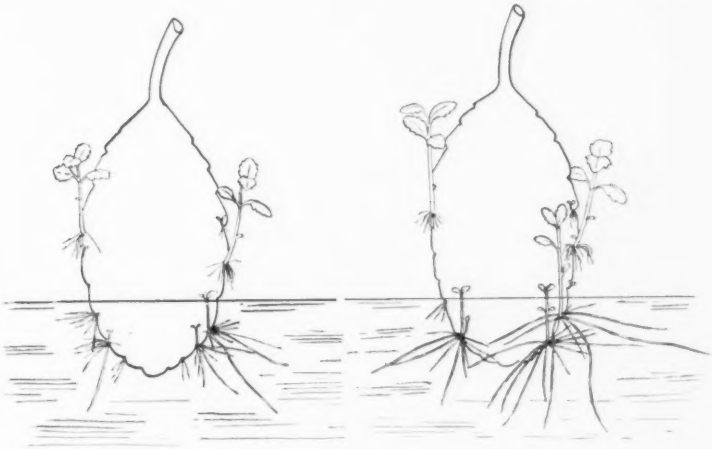

FIG. 13 FIG. 14

FIGS. 13, 14.—Same leaf as in figs. 11 and 12, after 45 and 52 days; on 33d day leaf was dipped with apex in water and now new shoots are formed in watered notches, which grow rapidly and soon reach size of two original shoots; proves that amount of water determines which notches shall grow into shoots.

16 days after the apex was put into water. It will be noticed that new shoots have grown out from three of the apical notches dipping in water. This never happened when the leaves remained in moist air. It can be shown that such a leaf when dipping in water absorbs water, and we are justified therefore in assuming that the increase in the contents of water in a notch or the starting of a current of water through the notch starts its growth.

We may compare the conditions for the initiation of the growth of a notch in a leaf to those of the growth of a seed, inasmuch as in both cases an absorption of water is necessary to initiate growth.

In both cases the water may play the rôle of accelerating the velocity of certain chemical processes which are needed for the formation of roots and shoots.

The experiment just described never fails, and we may therefore say with some justification that *in an isolated leaf suspended in moist air those notches will grow out first which by chance have at first the necessary supply of water (or of sap in general)*. Those shoots which grow out first will then automatically inhibit the growth of the other notches by drawing the solutes and the water toward themselves.

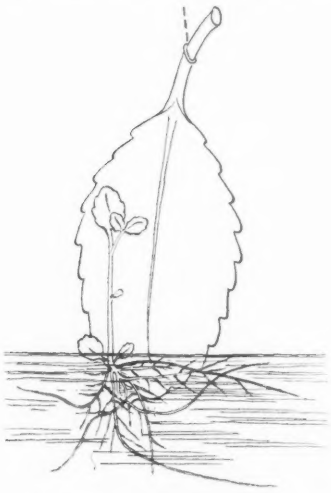

FIG. 15.—Leaf dipped with apex in water; drawn after 28 days: in such cases the shoot from one of watered notches will grow out so rapidly that as a rule it suppresses root and shoot formation in notches in middle of leaf, where growth is most rapid, when leaf is suspended in moist air, as comparison of figs. 15 and 11 will show.

This view is supported by another set of experiments. In the previous experiment the isolated leaves were first suspended in moist air and afterward allowed to dip into water. When we let the apex of the isolated leaf dip from the beginning into water, only those notches will give rise to shoots which are just under the level of the water or just above it (fig. 15). Such shoots grow more rapidly than the shoots of leaves suspended entirely in moist air, and this fact also suggests that it is the quantity of water which decides which notches grow out first. It is also noticeable that when an isolated leaf dips into water from the beginning the notches in the middle of the leaf, which would have given rise to roots (fig. 11) if the leaf had been suspended entirely in air, now generally fail to do so (fig. 15), if the leaf is not too large, presumably because the greater rate of growth of the notch dipping into water inhibits the growth of roots in the rest of the notches. With the greater

rate of growth of a notch is linked a greater inhibiting power upon the growth of the other notches, inasmuch as the flow of sap is directed toward a rapidly growing notch. The leaf in fig. 15 was then taken out of water and suspended in air on February 4. No new notches grew out, as was to be expected. The rapidly growing original shoot attracted all the sap available. A few roots started in some of the notches, but shriveled up almost as soon as they were formed (fig. 16). The results of this experiment are as constant as those of the previously mentioned experiment.

FIG. 16.—Same leaf as fig. 15: on 33d day leaf was removed from water and suspended in moist air; rapidly growing old shoot prevents any further growth in other notches.

These observations thus give us a rather clear view of the mechanism of correlation in an isolated leaf. In order to start the growth of a notch it is necessary that a stream of water should reach the notch. This will not happen as long as the leaf is part of a stem. Only when the leaf is old, ready to drop from the plant, do we notice occasionally that a shoot may form in the notches of a leaf while it is still attached to the plant, but this is rare. We can start the growth of notches at will, however, when the leaf is cut off. In that case that notch or those notches will grow first which happen to receive the greatest water supply (from within or without). Those which begin to grow more rapidly than the rest will automatically cause a current of sap toward themselves, in a way not yet understood. They thereby inhibit or retard the growth in the other notches. This inhibition can be overcome at any time by supplying more water to an inhibited notch from without, whereby we accelerate the rate of chemical reactions in this notch, which in turn will now cause a flow of sap toward itself, but we can also increase the flow of sap to certain notches from within. The writer's former observations have shown that the sap in the leaf can flow around a corner, a fact which suggests the existence of

many interlocking channels for the sap flow. It occurred to us that if we suspend such leaves in moist air with their longitudinal axes put horizontally (figs. 17, 18), the notches on the lower side of the leaf should form more shoots than the notches on the upper side, since the sap should collect in larger masses on the lower edge of the leaf. This is apparently the case, since very often shoots form only on the lower side of such a leaf, as in fig. 17 (where the notches in *a*, *b*, *c* had been removed before the experiment began). In fig. 18 three notches formed on the lower and one on the upper side. The

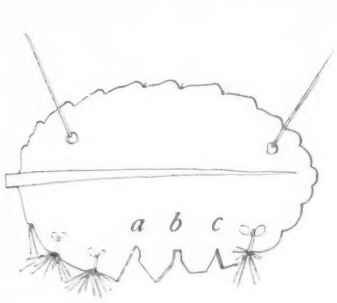

FIG. 17

FIG. 18

FIGS. 17, 18.—Leaves suspended in moist air with main axis in horizontal position: shows formation of shoots is favored on lower side, where water is bound to collect in larger masses; in fig. 17 notches at *a*, *b*, *c* had been removed.

experiment just mentioned and which has often been repeated supports the idea that the first shoots grow out where the water or sap collects, the water naturally having the tendency to flow downward.

Light is an important factor in the shoot production of the leaf of *Bryophyllum calycinum*. Isolated leaves kept in the dark produce a considerably smaller mass of shoots than their sister leaves kept in light, as the following experiment shows. Six leaves taken from different plants or nodes were suspended in the dark, either in moist air or were dipped with their apices in water; while their sister leaves were suspended in the same way but in light. Table XII shows the difference in the amount of shoot production.

It is obvious that in both cases the shoot formation is considerably greater in the light than in the dark. The experiment seems to indicate that either the process of assimilation contributes directly or indirectly to the formation of material for shoots in the leaf, or that the light in some other way contributes to the shoot formation. It is obvious that among the conditions which are to be considered in the production of equal masses of shoots by equal masses of leaves equality of illumination is of special importance. The writer observed deviations from the rule of equal production of shoots by equal masses of sister leaves when the leaves were able to partially cover or shade each other.

TABLE XII

	Shoots produced		Weight of leaves in gm.	Mgm. of shoots pro gm. of leaf
	Number	Weight in gm.		
I. 6 pairs of leaves suspended in moist air				in 30 days
In dark	3	0.016	11.65	1
In light	24	0.543	8.03	68
II. 7 pairs of leaves dipping in water				in 26 days
In dark	14	0.406	13.377	30
In light	17	1.725	17.270	100

In this paper we have considered only the production of equal masses of shoots by equal masses of sister leaves of *Bryophyllum calycinum*. The law is probably correct for leaves of *Bryophyllum* in general, provided a sufficiently large number of leaves are compared, so that the influence of individual differences in the leaves (age, amount of chlorophyll, etc.) is eliminated.

It is also very probable that this form of correlative inhibition of growth is not confined to the leaf of *Bryophyllum*, but is a more general phenomenon. Thus it seems to exist in the potato, where the growth of one bud seems to inhibit the growth of other buds of the same tuber, and perhaps for reasons similar to those set forth here.

Summary

1. Equal masses of sister leaves produce approximately equal masses of shoots in equal time and under equal conditions, even if the number of shoots varies considerably.

2. Those shoots which grow out first attract automatically the material available for shoot formation, thus withholding it from the other buds; the mechanism of this automatic attraction is not yet known.

3. These two factors, the limited amount of material available for growth and the automatic attraction of the material by the buds which grow out first, explain the inhibiting effect of these buds on the growth of the other buds.

4. The relative amount of water in a notch determines which notches give rise to shoots first; by supplying a liberal water supply from without or from within we can determine at will which notches shall grow out first.

ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH
NEW YORK CITY

ABNORMALITIES IN NICOTIANA[1]

H. A. Allard

(WITH TEN FIGURES)

Synanthic blossoms

Synanthy, or coalescence of blossoms, was noted in a species of tobacco, the seed of which was obtained from South America (S.P.I. no. 33708). This collection of seed gave red, purple, and white-flowered plants. In leaf characters the plants appeared fairly uniform. Although the seed was labeled *N. longiflora*, it may be said that these plants bear no resemblance to that species. They resemble *N. alata* Link and Otto (*N. affinis* Moore) and undoubtedly belong to this species. DeVries[2] mentions the occurrence of fasciation in *N. alata*.

The plant which furnished the abnormal blossoms produced beautiful white, exceptionally large blossoms. Three of the more striking abnormalities exhibited different degrees of double-blossom structure. In one instance three blossoms were concerned in the coalescence. These abnormal blossoms were distinguished by the following characteristics (figs. 1, 2, 3):

Abnormality no. 1.—A union of two blossoms which affected only the corolla tube and calyx. Although the corolla tubes were joined throughout their length, they did not communicate by an opening at any point. In all respects each blossom retained its individuality, possessing the normal number of 5 petals and 5 stamens, one pistil and ovary. In this double-blossom structure the corolla tubes merely adhered, so to speak, along their entire length. The calyx, however, showed a more intimate union, and appeared as one structure with 7 sepals.

Abnormality no. 2.—In this instance there is but one corolla tube inclosing the stamens, pistils, and the two ovaries. This

[1] Published by permission of the Secretary of Agriculture.

[2] DeVries, Hugo, Over de erfelijkheid der Fasciatiën. Bot. Jaarboek (dodoreea) VII. Aug. 1804 (see pp. 94 and 115).

corolla tube, however, is but little larger than the double-tube structure of blossom no. 1. Seven well developed petals were present and 8 filaments bearing anther sacs. One filament was a

FIG. 1.—Side views of abnormal blossoms: *1*, corolla tubes united but not communicating by openings; pistils and ovaries separate in each tube; *2*, single corolla tube inclosing both ovaries and stigmas; *3*, single corolla tube inclosing fasciated pistils and ovaries; ovary walls distinct within; *4*, normal blossom.—T. 1560.

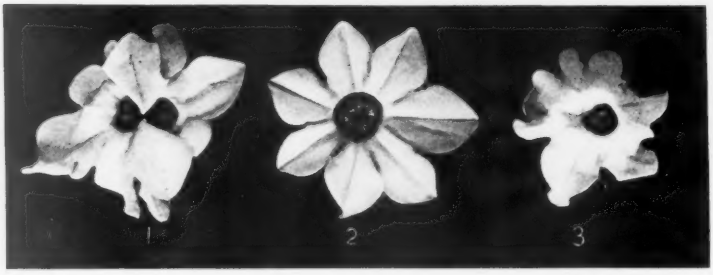

FIG. 2.—Views of abnormal blossoms *1*, *2*, and *3*, looking into throat.—T. 1559

trifle longer and flatter than in the normal blossom, and showed also a double-anther structure. The remaining 7 filaments and anthers appeared normal in all respects. Although this blossom possessed one corolla tube, which was somewhat larger than in the normal blossom, the ovaries and pistils remained distinct, as in blossom

no. 1. The petals were 7 in number, and the calyx possessed 7 sepals.

ABNORMALITY NO. 3.—In this instance the double-blossom structure has affected not only the corolla, but also the ovaries, pistils, and stamens, producing complete fasciation. In size, shape, appearance, and number of petals, the corolla and corolla tube are identical with blossom no. 2. The corolla possessed 7 lobes, and the calyx, similar in all respects to no. 2, possessed 7 sepals. Apparently only 7 stamens are present. One of these unmistakably

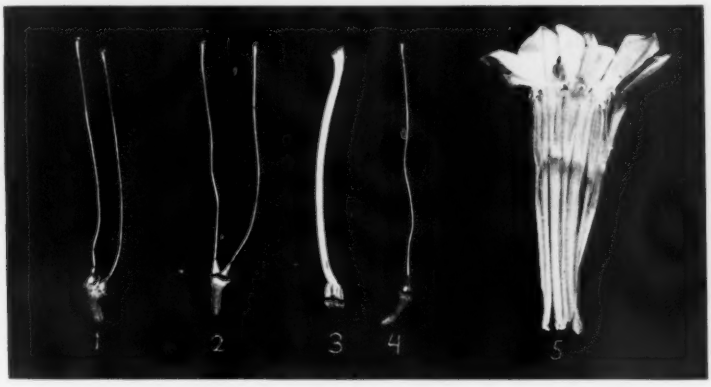

Fig. 3.—Corollas of abnormal blossoms *1*, *2*, and *3* removed, showing ovary and pistil structures; *4*, ovary and pistil of normal blossom; *5*, opened corolla of *3*, showing fasciation of pistils and ovary.—T. 1561.

has a double-anther structure. There is some indication of a third anther sac, although this cannot definitely be determined from observation. The filament of this structure was very broad and much flattened throughout. The pistil structure showed a broad, double stigmatic surface, and a broad, much flattened style leading down to a double ovary structure. Although the ovaries were united, each ovary appeared to possess its own walls. In other words, the ovary structure appeared as two closely appressed single ovaries.

ABNORMALITY NO. 4.—In this instance three blossoms are involved in the coalescence (fig. 4). The two blossoms at the right

have a common corolla tube which incloses two separate ovaries, each with its own pistil, as in abnormality no. 2. In this blossom 9 filaments and anthers were also present. The blossom at the left was normal in all respects, except that the corolla tube throughout its length was united with the double corolla tube structure at the right, but did not communicate by an opening at any point. A common calyx possessing many sepal-like divisions inclosed these blossoms. This peculiar blossom formation represents virtually a combination between abnormalities no. 1 and 2.

FIG. 4.—Fasciation involving 3 blossoms; union of 2 blossoms at left with common corolla tube inclosing 2 separate ovaries; at right single normal blossom with corolla tube united throughout to double corolla tube structure at left.—T. 1562.

In other plants grown from the same lot of seed, various examples of similar abnormalities in the blossoms have appeared from time to time. In one instance a double-blossom structure appeared as in abnormality no. 2, except that the common corolla possessed 9 instead of 7 lobes; 9 stamens were also present. In other instances showing similar doubling of the blossoms, 11 distinct stamens and 11 distinct corolla lobes were present. Experiments have shown that these abnormalities are more or less hereditary, and, for that reason, the predisposing cause is associated with the germ plasm.

Catacorolla in blossoms of Nicotiana Tabacum as a result of mosaic disease

The blossom abnormality known as catacorolla has received considerable treatment in the literature bearing on teratological phenomena. Catacorolla has been noted in plants of many families. Among the Solanaceae various species of *Nicotiana* have shown instances of catacorolla. PENZIG[3] described and figured

[3] PENZIG, O., Miscellanea Teratologica. Mem. del Reale Instituto Lombardo, 15:147–212. 1884.

instances of catacorolla in *N. Tabacum*, but did not determine its relation to the inherited organization of the plants.

WHITE[4] describes rather fully and illustrates the abnormalities of petalody, pistillody, and catacorolla in certain species of *Nicotiana*. He gives an interesting discussion of the occurrence of catacorolla in F_2 plants of the cross *N. Langsdorfii* and *N. alata*, the parents of which were normal. WHITE found that the type of catacorolla

FIG. 5.—Various phases of catacorolla in *N. Tabacum* produced by mosaic disease; limb of corolla in most instances has undergone excessive development, greatly increasing circumference; although structures simulate doubling in appearance, corolla structure alone is involved, and doubling is only apparent; in fifth blossom (upper row) a very beautiful ascidium or pitcher-like structure is shown.—T. 1704.

with which he worked was hereditary, and in crosses with normal plants it was found to be more or less intermediate in its expression.

Blossom abnormalities associated with fasciation have also been described and illustrated. Some of these resemble very closely certain phases of catacorolla. WHITE[5] describes fasciation

[4] WHITE, O. E., Studies of teratological phenomena in their relation to evolution and the problems of heredity. Amer. Jour. Bot. **1**:23–36. 1914.

[5] WHITE, O. E., The bearing of teratological development in *Nicotiana* on theories of heredity. Amer. Nat. **47**:no. 565. 1913.

which occurred in Cuban tobacco grown in Cuba. PAOLINI[6] describes and gives an excellent illustration of fasciation occurring in the variety Samsum (*N. Tabacum*), grown in Asia Minor. This is evidently another instance of extreme fasciation similar to that which appeared in the Cuban variety in Cuba. SCARPUZZA[7] described and illustrated fasciation similar to that observed by PAOLINI.

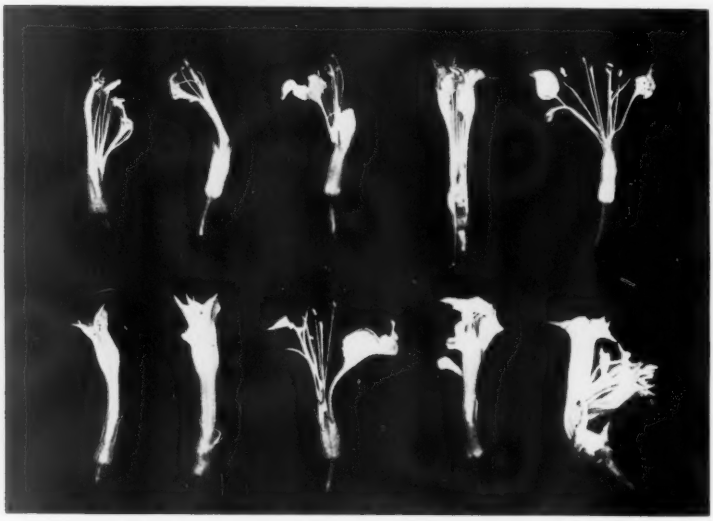

FIG. 6.—Catacorolla in *N. Tabacum* produced by mosaic disease; in most instances development has been suppressed in these blossoms; ascidia shown in third and fifth blossoms (upper row); last blossom in lower row shows tendency toward fasciation; 2 blossoms, one nearly normal, another abnormal, are inclosed in common calyx.—T. 1576.

During the writer's investigations of the mosaic disease of tobacco, catacorolla has been one of the most common abnormalities produced in the blossoms of *N. Tabacum* in connection with the

[6] PAOLINI, V., Caso di Concrescenza in una Pianta di Samsum. Boll. Tecnico del R. Instituto Sperimentale in Scafati (Salerno). **6**:no. 4. 1907.

[7] SCARPUZZA, A., Di Alcune Anomalie Morfologiche su Piante di Aya Solouc. Boll. Tecnico del R. Instituto Sperimentale in Scafati (Salerno), anno VI, no. 4; July–August, 1907.

disease. All phases of catacorolla have been noted. Very frequently the normal development of the corolla has been considerably exceeded, producing large and very showy blossoms, with a much folded and greatly increased circumference or border (fig. 5).

Although the tobacco blossom is normally gamopetalous, the parts of the corolla may be more or less completely separated by clefts into petaloid segments. In some instances these have been replaced by very striking and beautiful ascidia or pitchers, borne

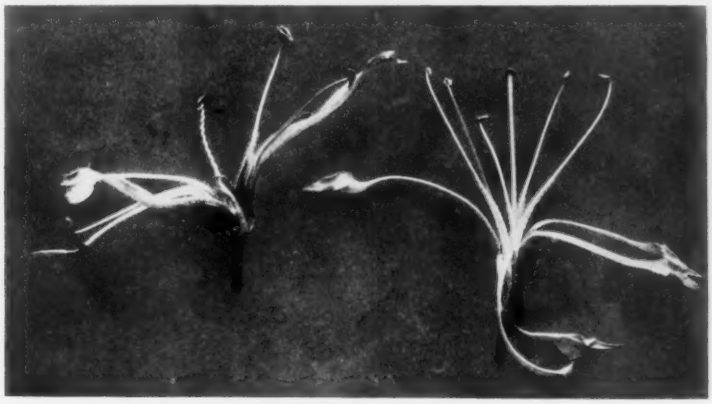

FIG. 7.—Abnormal blossoms of *N. Tabacum* produced by mosaic disease of tobacco; corolla development has been almost completely suppressed; in blossom at left pistil shows peculiar twisted structure; in blossoms at right, representing the 5 corolla lobes normally present, stamens and pistils are normal in development; hairy portion of filaments in normal blossoms is adnate to corolla tube.—T. 1598.

upon long, slender, tubular stalks (see fifth blossom, top row, fig. 5, and third and fifth blossoms, top row, fig. 6). The blossom at the right in fig. 7 shows a complete separation of the corolla into 5 distinct and nearly equal petaloid segments. In this blossom the normal development of the stamens and pistils has been but little, if at all, interfered with. Although nothing is known concerning the development of the various structures of the flower in connection with the mosaic disease, it appears that disturbances in the petal primordia are more likely to occur than in the primordia of other structures.

Although the mosaic disease of tobacco may produce all phases of catacorolla in the blossoms of *N. Tabacum*, other species rarely, if ever, show this abnormality in connection with the mosaic disease. Although petunias, *Datura Stramonium*, *Nicotiana glauca*, *N. longiflora*, *N. silvestris*, *N. alata*, etc., are readily infected with the mosaic disease of tobacco, the writer has never observed the occurrence of such abnormalities in the blossoms of these plants affected with the mosaic disease.

FIG. 8.—Plant of first generation of cross Maryland Mammoth (♀)× Yellow Pryor (♂), showing development of growing points; character appeared in many plants of first generation of this cross; plant shown was grown in 8 in. pot; taller branch is 28 in. high; smaller 21 in. in height.—T. 1602.

Likewise, the blossoms of *N. glutinosa* affected with a mosaic disease similar to but not identical with the mosaic disease of tobacco have never yet shown the catacorolla abnormality. It is interesting to note, however, that first generation plants of the cross *N. Tabacum* (♀)×*N. glutinosa* (♂) show all phases of catacorolla when affected with the mosaic disease of *N. glutinosa*, to which these hybrids are susceptible. These facts indicate that catacorolla is more readily induced by the mosaic disease in blossoms of *N. Tabacum* than in many other species of *Nicotiana*.

Normal blossoms and abnormal blossoms showing all degrees of catacorolla may frequently be shown on the same branch of the inflorescence. Although the inciting cause is associated with the mosaic disease of tobacco, conditions which disturb normal growth, such as cutting back, starvation, etc., tend to accentuate the expression of the abnormality.

WHITE's observations show that catacorolla may sometimes appear suddenly in connection with a cross and persist in the

hereditary mechanism of the tobacco plant. The writer's experiments show that catacorolla originating as a result of the mosaic disease of tobacco is not inherited. For this reason the causal factor is external or accidental in its nature, and does not extend its influence to the constitution of the germ plasm. Although it has not been definitely established that the primary cause of the mosaic diseases affecting *N. Tabacum* and *N. glutinosa* is parasitic

FIG. 9.—Upper row: blossoms possessing 6 and 7 corolla lobes; middle row: blossoms with 3 and 4 corolla lobes; lower row: normal 5-lobed blossom at left, abnormal blossom at right.—T. 1763.

in its nature, it is evident that the blossom abnormalities observed in *N. Tabacum* as a result of the mosaic disease are analogous in their origin to the abnormalities, monstrosities, galls, etc., due to insects, fungi, bacteria, etc.

The development of two growing points

In the cross Md. Mammoth (♀)×Yellow Pryor (♂), a number of young plants of the first generation were characterized by two

growing points (fig. 8). These were evident when the plants were very small. As the plants became older, one of the growing points was not infrequently outgrown by the stronger branch. In other instances the two growing points maintained almost equal vigor, producing two well developed stalks which finally blossomed. In the Maryland Mammoth variety there seems to be a tendency to develop bifurcation of the main stem in a small percentage of the plants. This feature, however, has usually made its appearance rather late in the development of the plant.

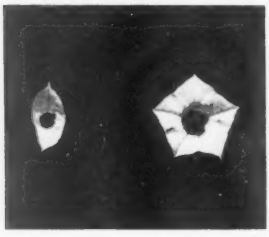

FIG. 10.—*N. Tabacum*, showing abnormal form at left, with only 2 petals; normal blossom with 5 petals from same plant shown at right; this singular blossom occurred on a plant of second generation of a cross between 2 distinct varieties of *N. Tabacum*, and was the only abnormal blossom produced by plant.—T. I. 2188.

Corolla lobes abnormal in number

In the normal tobacco blossom the corolla has 5 lobes and 5 stamens. In abnormal blossoms the number of corolla lobes may be greater or less than the normal number. Blossoms abnormal with respect to the number of corolla lobes are shown in figs. 9 and 10. The blossoms in the top row (fig. 9) were obtained from a plant of the second generation of the cross *N. Tabacum* (♀)×*N. silvestris* (♂), and were a deep red. Nearly all the blossoms produced by the plant possessed 6 or 7 corolla lobes. A few normal blossoms were produced. The plant was grown in an 8-inch pot and appeared to be normal in all respects.

The blossoms shown in fig. 9, rows 2 and 3, were obtained from a single plant of ordinary tobacco (*N. Tabacum*) and were pink in color. Although a few blossoms possessed the normal number of corolla lobes (5), the majority possessed only 3 or 4 lobes. The plant producing these blossoms showed typical symptoms of "Frenching," which appears to be a nutritional disturbance associated with unfavorable soil conditions. This plant was grown in an 8-inch pot.

An examination of the blossoms showed that the number of stamens in most instances was the same as the lobes of the corolla. The relations are given in table I.

TABLE I

Blossom no.	Row	Corolla lobes	Stamens	Result
1 (red)	Upper	7	7	Calyx and pistil normal
2 "	"	7	6	" " " "
3 "	"	6	6	" " " "
4 "	"	6	6	6 calyx lobes, pistil normal
5 (pink)	Second	3	4	Calyx and pistil normal
6 "	"	4	4	4 calyx lobes, pistil normal
7 "	"	4	4	" " " " "
8 "	"	4	4	" " " " "
9 "	Third	5	5	Blossom normal in all respects
10 "	"	4	4	Calyx and pistil normal

In blossom no. 10 a small, slender division was also evident in addition to the 4 large, equal lobes. In all the blossoms the stamens present were normal in their development.

In fig. 10 a blossom with a 2-lobed corolla is shown in comparison with a normal, 5-lobed blossom of the same plant. This 2-lobed blossom occurred on a plant of the second generation of a cross between two distinct varieties of *N. Tabacum*, and was the only abnormal blossom produced on the plant.

Bureau of Plant Industry
Washington, D.C.

CHANGING DIATOMS OF DEVILS LAKE

CLARENCE J. ELMORE

During the summer of 1915 I spent some time at the Biological Station of the University of North Dakota at Devils Lake, investigating the diatoms of the lake. Before this considerable diatom material had been sent to me by Dr. R. T. YOUNG of the University, who is conducting the biological survey of the lake.

The immediate practical object in the survey is to determine the organisms in the lake in relation to the fish that might be able to subsist upon them, and diatoms being the most abundant of microscopic plants, deserve special attention in this connection. At present the stickleback, *Eucalia inconstans*, is the only species of fish in the lake, notwithstanding the fact that food is abundant. This species, however, is common.

The lake is passing through a rapid transition. It was formerly a fresh-water lake fed by streams, and at that time it contained large numbers of fish, but the lake is rapidly becoming lower. From 1883 to 1912 it fell 14 ft., a fall of about half a foot a year. It has now no apparent inlet or outlet, and the water is becoming salt. The salinity, however, is quite different from that of sea water. It differs somewhat in different parts of the lake and at different seasons of the year, but the following analyses made by Dr. F. H. HEATH of the University of North Dakota in the summers of 1914, 1915, and 1916 will give a general idea of the condition of the water. No complete analysis was made in 1915, but the total amount of solids in that year was greater than in 1914 or 1916, due to the lower level of the water.

	1914	1915	1916
Carbonate (CO_3)	254	213	.....
Bicarbonate (HCO_3)	447	639	.....
Silica (SiO_2) variable	370	.....	242 and 69
Sulphate (SO_4)	6231	.....	6706
Fe_2O_3 and Al_2O_3	.....	.....	121
Calcium (Ca) variable	.....	.....	86.5
Magnesium (Mg)	598	.....	579
Chlorine (Cl)	1106	.....	1284
Total solids	11,980	14,477	13,020

These analyses show about 1 per cent of solids in the lake, or about one-third of the amount in ocean water. This comparatively rapid increase in salinity has produced a corresponding change in the diatoms of the lake, as well as in all the other organisms that it contains. We have no knowledge of what diatoms were in the lake when the water was fresh, but we can safely assume that they were all of species commonly found in fresh water elsewhere, perhaps the same as in Court Lake, a fresh-water lake which was formerly a part of Devils Lake.

In my work I identified 56 species of diatoms in the lake. Of these, 25, as reported elsewhere, are genuine fresh-water species; 20 are species that are found in either fresh or brackish water; 3 are in brackish water only; 2 are reported as being found in fresh, brackish, or salt water; 2 in brackish or salt water; and 4 as marine only. It is possible that when the water in the lake was fresh 50 of these species, that is, all but the 4 marine ones and the 2 that are brackish or marine, were living in it; however, this is not likely. It is probable that there was then a much larger proportion of fresh-water species, as there usually is in fresh water, and fewer of those of varied habitat. As the water became more saline, however, diatoms adapted to either fresh or brackish water gained a foothold, then those adapted to either brackish or salt water, and finally the 4 marine species. One of these marine species, *Chaetoceros elmorei* Boyer, classed as marine because the genus is a marine one, was identified by C. S. Boyer as a new species. It is not likely, however, that it originated in this lake, and it is probably to be found elsewhere.

The importation of marine species so far inland is easily accounted for. It would be perfectly possible for them to be carried in the air, but adhering to migratory birds is a much more probable explanation.

The 25 species of fresh-water diatoms present the greatest anomaly. There is nothing in their appearance to indicate that they have been in any way modified by their changed environment.

There are several smaller lakes in the vicinity of Devils Lake which were formerly part of the main lake, but have been separated from it by the lowering of the water. The analysis of the water

made in 1916 by HEATH shows the total solids in the main lake to be 13,020, or about 1.3 per cent; in Minnewaukon Bay above the grade, 0.4464 per cent; Court Lake, 0.12 per cent; and Lake I, 0.1328 per cent. The water in all of these lakes shows the same large amount of magnesium sulphate.

These conditions of salinity are correlated with interesting differences in the diatoms. The portion of Minnewaukon Bay from which the sample was taken was formerly part of the main lake and its water had about the same degree of salinity. But within the past year a highway grade has been made, cutting it off, and it is now connected with the main lake only by a culvert. Through this culvert the main lake receives about 2,000,000 gallons of water daily. This leaves the water in the bay practically fresh. In a collection made in this bay 14 species of diatoms were found, all but one of which are also found in the main lake. This one species, *Stephanodiscus niagrae*, is a fresh-water species. In this case a change in the condition of the water of from 1.3 per cent to 0.4464 per cent of solids has in one season made practically no change in the diatoms.

Lake I contains 0.1328 per cent of solids, or about one-third as much as Minnewaukon Bay. Instead of having been separated from the main lake only a few months, as in the case of Minnewaukon Bay, it has been separated for about 5 years. In this lake 24 species were found, 6 of which are not found in the main lake. These 6 are all fresh-water species.

Court Lake contains 0.12 per cent of solids, nearly the same as Lake I, but of the 22 species of diatoms found in it, 13 are not found in the main lake, and all of these 13 are fresh-water species; but Court Lake has been separated from the main lake for about 100 years. Since the main lake became salt, Court Lake has not been connected with it. These 13 species not found in the main lake, therefore, may have been originally in it and have died out on account of the saltness of the water; or they may have been introduced into Court Lake after the separation; or, what is more likely, some may have been in the original lake and others have been introduced later.

The fact that little change has been made in the diatoms by the change of water in the branch of Minnewaukon Bay would indi-

cate that diatoms are not very sensitive to such changes. Also, the fact that Lake I, which contains about the same amount of solids as Court Lake, but has recently been connected with the main lake, has a diatom flora much more like the main lake than like Court Lake, also indicates that diatoms are slow in responding to changes in environment.

No marine species were found in any of the outlying lakes, but as they are comparatively rare in the main lake, and the other lakes have been less carefully explored, this fact probably has no significance. More careful collecting may show them there also.

In a spring at Sully's Hill on the shore of the lake, but at an elevation of 50 ft. or more above it, 9 species were found, 3 of which were found in the lake and 6 not found in it. These probably have no relation to the diatoms of the lake, for there has never been any connection between the water of the two places, and these diatoms are all of species found commonly in fresh water everywhere.

In ditches along railroads and in pools 26 species were found, 17 of which were found in the main lake and 9 of which were not. The composition of the water in these places varies greatly. After rains, when they are filled, the water is practically fresh, but as it evaporates it becomes considerably concentrated. This, together with the fact that this land was once covered by the lake, explains the presence of the forms commonly found in brackish water. Some of these facts are summarized in following table I.

TABLE I

Place	Species in main lake	Not in main lake	Percentage of solids	Time separated from main lake	Habitat as reported elsewhere					
					Fresh	Marine	Fresh and brackish	Brackish	Marine or brackish	Fresh, brackish, or marine
Main Lake	56	0	1.3	.....	25	4	20	3	2	2
Minnewaukon Bay	13	1	0.4464	6 months	6	1	6	0	0	1
Court Lake	9	13	0.12	100 years	16	0	4	1	1	0
Lake I	18	6	0.1328	5 years	12	0	10	1	1	0
Pools and ditches	17	9	.....	.....	14	0	1	3	1	2

The diatoms of this region illustrate what has commonly been observed elsewhere, that many of them adapt themselves readily

to changes in environment. Here there are marine and freshwater species living together under semimarine conditions, and in Minnewaukon Bay, where the water changed from saline to fresh, the diatoms that had been living in the saline water seemed to have been in no way affected in one season by the change. In Court Lake, the water of which has never been salt, there is one species whose habitat is reported as "marine or brackish." Its presence here may be explained by the nearness of Court Lake to salt water, making it easy for it to be introduced; and its continuing to live there may be explained by its adaptability to various environment.

Should the lake continue to diminish in size, its salinity will probably increase; and at the same time other bays will be cut off and become separate lakes. These changes will furnish interesting material for study, not only of the diatoms, but of all other organisms inhabiting the lake.

GRAND ISLAND COLLEGE
GRAND ISLAND, NEB.

BRIEFER ARTICLES

REGENERATION OF BRYOPHYLLUM CALYCINUM

(WITH TWO FIGURES)

In two articles on regeneration of *Bryophyllum*, LOEB[1] bases his theories of inhibition and correlation in the regeneration of *Bryophyllum* upon the results of numerous experiments with severed leaves and portions of stems, and upon the negative results obtained with "normal plants." After reading these articles, the writer recalled numerous instances of regeneration seemingly at variance with the experiments described.

Experiments by LOEB indicate that under suitable conditions whole leaves severed from the plant produce shoots from only a few notches. The writer has found the number of notches which produce shoots to vary from one or two to all of the notches, when whole leaves were placed in the moist air of a Wardian case, or, more frequently, on damp soil in the garden. The growth of all or many notches of whole leaves does not coincide with LOEB's results, and furthermore is in direct opposition to his theory of the flow of certain substances in the leaf determined by the first notches which begin to grow, and the consequent inhibitory effect produced upon the growth of other notches. In view of LOEB's results and theories, more striking even than the growth of many notches on severed leaves is the production of roots and shoots in the notches of leaves attached to growing plants. In introducing his subject, LOEB asks, "Why does a leaf not form roots and shoots in its notches so long as it is in connection with a healthy plant?" (*loc. cit.* **60**:250). And again, under theoretical remarks, "When a plant is normal, it is almost or possibly absolutely impossible to induce the notches of a leaf which is connected with the plant to grow" (*loc. cit.* **60**:274).

Pot-grown plants of *B. calycinum* in the writer's possession have frequently grown both shoots and roots from leaf notches while the leaves were in connection with the plant. Early in the spring of 1917 a large plant of *Bryophyllum* (fig. 1) began to produce shoots from the leaves

[1] LOEB, JACQUES, Rules and mechanism of inhibition and correlation in the regeneration of *Bryophyllum calycinum*. BOT. GAZ. **60**:240–276. 1915; Further experiments on correlation of growth in *Bryophyllumca lycinum*. BOT. GAZ. **62**:293–302. 1916.

more abundantly than the plants often do. The accompanying photographs were taken May 12, when shoot production had reached its maximum. It was not necessary to induce the notches to grow; they grew freely under ordinary room conditions, and with only the usual attention which a pot plant in a residence receives.

A number of the leaves of the plant (fig. 2) produced shoots from all the notches or from all except the basal notches, a phenomenon which, to accord with LOEB's theories, should take place only under very special conditions. The plant appears to be a "healthy plant," as healthy and

FIG. 1

FIG. 2

FIGS. 1 AND 2.—Fig. 1, large pot-grown plant of *Bryophyllum calycinum* producing shoots from many of its leaves; fig. 2, leaf of plant shown in fig. 1, with shoots growing from all except the two small basal notches.

vigorous a plant as the writer has ever seen. Whether or not it is a "normal plant," as a normal plant is conceived of by LOEB, is difficult to say, for nowhere does he define a "normal plant." He does state: "If, however, the flow of substances in a plant is abnormal, either because the roots or the apical parts or both have suffered, a growth of shoots may occur in moist air from the notches of leaves which are in contact with the plant." There is no indication that either the roots or the apical parts have suffered; the plant appears healthy, and has had no accident.

A "normal plant" will probably be interpreted to be a "healthy plant," inasmuch as these two terms are used interchangeably in con-

nection with statements concerning the growth of notches of leaves attached to plants. It would seem, therefore, that the conclusions reached by LOEB are not substantiated by the behavior of the plants in question.—E. LUCY BRAUN, *University of Cincinnati.*

MISTLETOE VS. MISTLETOE

(WITH ONE FIGURE)

The specimen shown in fig. 1 was collected near Tucson about three years ago by Professor J. J. THORNBER of this University. *Phoradendron flavescens*, the larger plant, acting both as partial parasite and host, is found on species of *Quercus*, *Fraxinus*, and *Juglans;* while *P. californicum*, the smaller one, is a common parasite on *Parkinsonia*, *Prosopis*, and *Acacia*. Although the mistletoe is of common occurrence on palo verde and mesquite in this region, the writer has never before seen one species parasitic on another. It is interesting to consider water and salts, and possibly other materials, as having to pass successively through the vascular systems of three different plants before they reach the cells wherein they enter into metabolic activities. With transpiration much stronger in *P. flavescens* because of its larger transpiring surface, it would appear as if the second species must have a rather difficult time in securing a sustaining share of the ascending stream of sap. Possibly physiologists could find a higher osmotic pressure in the smaller species to account for its ability to maintain an existence in its peculiar location.—J. G. BROWN, *University of Arizona.*

FIG. 1.—*Phoradendron californicum* parasitic on *P. flavescens*.

CURRENT LITERATURE

MINOR NOTICES

A textbook of botany.—The second part of GANONG's *Textbook of Botany* has appeared,[1] including a presentation of the plant groups, and also the ecological classification of plants. In the first chapter the phylogenetic connections of the major plant groups are presented; while the subsequent chapters give a general account of the different groups, using selected forms as illustrations. The author is so well known as a teacher that it is hardly necessary to say that the presentation, following the thought he has had in mind, is thoroughly well done.—J. M. C.

Manual of woody plants.—TRELEASE[2] has published a small pocket manual of the woody plants used for decorative purposes. The intention of the author "is to make it possible for any careful observer to learn the generic and usually the specific name of any hardy tree, shrub, or woody climber that he is likely to find cultivated in the United States." The book contains 782 species in 247 genera. Its keys and descriptions, with the help of the glossary, should enable those untrained in botany to recognize woody plants under cultivation in parks and other ornamental grounds; while its size makes it available as a pocket companion.—J. M. C.

The sweet pea.—The rapid advance in plant pathology is bringing forth popular books on the diseases of special crops for the use of commercial growers. These works in order to meet the demand of the growers must be broader than most Experiment Station publications. The most recent publication of this kind is by TAUBENHAUS,[3] whose studies in the Delaware Agricultural Experiment Station have given him an especially good preparation for this work. The book gives a review of the history, evolution, and classification of sweet peas; a thorough discussion of cultural methods; and the diseases (including insect pests) and methods for their control. The work is very carefully prepared and well illustrated, and the discussions so clear and concise that the grower will find it very helpful.—MEL. T. COOK.

[1] GANONG, WILLIAM F., A textbook of botany for colleges. Part II. 8vo. pp. ix+391–595. *figs. 275–400.* New York: Macmillan. 1917. $1.00.

[2] TRELEASE, WILLIAM, Plant materials of decorative gardening: The woody plants. 16mo. pp. 204. Urbana: Published by the author. 1917.

[3] TAUBENHAUS, J. J., The culture and diseases of the sweet pea. New York: E. P. Dutton & Co. 1917.

Botany of crop plants.—ROBBINS[4] has written a most successful botanical textbook with a direct bearing on agriculture, and it will be welcomed by many teachers in botany. The work is the outcome of a course in Freshman botany which the author has been giving for several years, and is intended for both agricultural and non-agricultural schools. It is divided into two parts. The first part consists of 8 chapters and includes general or fundamental botany. It is devoted entirely to angiosperms and would be somewhat better for a college textbook if more extensive. The second part gives excellent discussions of most of our important agricultural crops, including general descriptions of the plants, their flowers and fruits, with discussions of their history, uses, and distribution. Some of these discussions include maps and keys. Each chapter closes with an excellent bibliography. The value of the book would be greatly increased by laboratory outlines, by chapters on lower plants in the first part, and by chapters on plant breeding, forestry, plant pathology, and other related subjects in the second part.—MEL. T. COOK.

NOTES FOR STUDENTS

Addisonia.—The third number of the second volume of this journal contains colored plates and popular descriptions of *Harrisia gracilis*, *Epidendrum oblongatum*, *Aesculus parviflora*, *Micrampelis lobata*, *Bomarea edulis*, *Aster tataricus*, *Pachyphytum bracteosum*, *Harrisia Martini*, *Oncidium pubes*, and *Raphiolepis ovata*.—J. M. C.

Subalpine plants of the Rocky Mountains.—Continuing his series of studies of the flora of the Rocky Mountains already noted,[5] RYDBERG[6] has made an analysis of the vegetation of the subalpine zone. Lists of species found in the different formations are given, and three classes are distinguished according to whether the plants are restricted to the northern or to the southern Rockies, or are common to both.—GEO. D. FULLER.

Revegetation of Taal volcano.—Swept bare of plants by an eruption in 1911, the slopes of Taal volcano have afforded an excellent opportunity for the study of revegetation within the tropics. Records by GATES[7] show that the grasses are prominent among the pioneers, followed by shrubs and small trees. In contrast with the conditions at Krakatau, ferns are found to be

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[4] ROBBINS, W. W., Botany of crop plants. Philadelphia: P. Blakiston's Sons. 1917.

[5] BOT. GAZ. **62**:83–84. 1916; **63**:423–424. 1917.

[6] RYDBERG, P. A., Phytogeographical notes on the Rocky Mountain region. VII. Formation of the subalpine zone. Bull. Torr. Bot. Club **44**:431–454. 1917.

[7] GATES, F. C., The pioneer vegetation of Taal volcano. Phil. Jour. Sci. **9**:391–434. 1914.

———, The revegetation of Taal volcano, P.I. Plant World **20**:105–207. 1917.

relatively unimportant. Lists of species present three and four years after the eruption are given.—GEO. D. FULLER.

Soil moisture.—The increasing demand for the use of quantitative studies of soil moisture in ecological and agricultural studies makes ALWAY'S[8] investigation of methods for the accurate determination of the hygroscopic coefficient very timely. HILGARD'S method is found to give reliable results, but certain changes in details of manipulation are found to be desirable as matters of convenience. Two important conclusions are that the amount of hygroscopic moisture absorbed increases with rise of temperature, and that 12 hours' exposure to saturated atmosphere is sufficient, provided the soil layer is very shallow.—GEO. D. FULLER.

A new disease of wheat.—SMITH[9] has announced the appearance in the Middle West of a new disease of wheat, which he says "is a matter of much concern." The disease has been known since 1902, but the destruction of winter wheat in 1917, which has generally been ascribed to winter-killing, led to the suspicion that a part of the loss might be due to this new disease. It is believed to be of bacterial origin, and promises to be difficult to control.

The disease attacks not only the leaves, glumes, awns, rachis, and stalk, but sometimes also the kernel itself, suggesting that it is carried over from year to year on the seed.—J. M. C.

Vegetation of Colorado.—A valuable bulletin by ROBBINS[10] is a continuation of his work on the vegetation of Colorado in its relation to climate.[11] Comprehensive tables show what is known about the climates of the state as to temperature, precipitation, frost, humidity, length of growing seasons, etc. Following the statistical matter is a brief account of the chief types of vegetation and their relation to agriculture, under the following headings: grass-steppe, shrub-steppe, chaparral, pinyon pine-juniper woodland zone, yellow pine forest zone, lodgepole pine forest zone, white fir forest zone, Engelmann spruce forest zone. Maps and charts are freely employed. Useful lists of the more important trees, shrubs, and herbs are given. Publications such as this for other states would be of great value to botanists as well as to farmers.—FRANCIS RAMALEY.

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[8] ALWAY, F. J., and others. Some notes on the direct determination of the hygroscopic coefficient. Jour. Agric. Research **11**:147–166. 1917.

[9] SMITH, ERWIN F., A new disease of wheat. Jour. Agric. Research **10**:51–53. *pls. 4–8.* 1917.

[10] ROBBINS, WILFRED W., Native vegetation and climate of Colorado in their relation to agriculture. Bull. no. 224 Colo. Agric. Exper. Sta., Ft. Collins, Colo. 1917.

[11] BOT. GAZ. **49**:256–280. 1910.

Cleistogamy in Heteranthera.—WYLIE[12] has discovered that *Heteranthera dubia* is cleistogamous, and his investigation of the situation has led him to some interesting conclusions and questions. As he remarks, this plant "has developed a vegetative body well adapted to the submersed life, as shown by its vigorous and successful growth. It has failed, however, to attain floral specialization adequate to insure cross-pollination." He finds that there is no possibility of cross-pollination, except through flower elongation, "so that if seeds are to be set with certainty and in considerable numbers, it must be through close pollination under water, excepting the relatively few flowers so situated that they can reach the air, and these also seem to have acquired the habit of self-fertilization." He suggests that this species is a favorable one for experimental study in plant-breeding, since it grows readily, and if kept submerged sets seeds freely without further attention.—J. M. C.

A living physical system.—BRIGGS'S[13] clear-cut picture of the living plant as a physical system which is absorbing energy and performing useful work is significant of the present trend of botanical thought. He suggests that the doctrine of vitalism is being restricted more and more as our knowledge of plant phenomena increases. He summarizes the situation as follows: "The mechanism of plant processes, not at present explainable on a physico-chemical basis, would be termed by the vitalistic school as 'vital,' by the physico-chemical school as 'unknown.'" He treats the subject under the following heads: (1) the efficiency of the plant system, (2) the growth rate, (3) gas exchange between the leaf and the air, (4) diffusion through perforate septa, (5) the ascent of sap. In closing he emphasizes the fact that as a means of efficiency in plant production it is important to have the fullest possible understanding of the physical and chemical processes associated with growth.—GEO. B. RIGG.

Leaf duration in evergreens.—In studies embracing 9 gymnosperms and 22 angiosperms, growing in the state of Washington, PEASE[14] has investigated the duration of leaves and has endeavored to account for the variations displayed. The leaf age limit reaches from about a single year in *Rhamnus Purshiana* to 23 years in *Taxus brevifolia*. From determinations upon approximately 100 twigs of each species grown under a variety of conditions, graphs are plotted showing the range for each. Some of the factors found to be efficient in affecting duration are (1) age, mature trees having older leaves;

[12] WYLIE, ROBERT B., Cleistogamy in *Heteranthera dubia*. Bull. Lab. Nat. Hist. State Univ. Iowa **7**:48–58. 1917.

[13] BRIGGS, LYMAN J., The living plant as a physical system. Jour. Wash. Acad. Sci. **7**:89–111. 1917.

[14] PEASE, VINNIE A., Duration of leaves in evergreens. Amer. Jour. Bot. **4**:145–160. *figs. 12*. 1917.

(2) shade, increasing permanency; (3) wind, tending to decrease duration; (4) moisture, tending to lengthen duration; and (5) bog habitat, causing the same early fall as dry habitat. In general, factors which cause increase in transpiration are accompanied by decrease in leaf duration, while those factors tending toward decrease in photosynthetic activity are accompanied by increased duration. The author of the paper is to be commended upon its good organization.—GEO. D. FULLER.

Physical factors in plant distribution.—The recent advances along the line of devoting more attention to the factors controlling vegetation and the progress made in more correctly evaluating these factors have been discussed by SHREVE,[15] who has also pointed out the striking contrasts in the physical conditions of mountains in humid and arid regions.[16] The contrasts in humidity are most marked, but are manifest also in temperature and light. Examples are seen in the Blue Mountains of Jamaica, with a daily temperature range of 6–10°, compared with the Santa Catalina Mountains of Arizona, with a daily range of 40–65° and corresponding annual amplitudes. These and other differences enumerated result in plant associations where a stratified rain forest in the former region, with large trees, under trees, shrubs, large herbs, and small hygrophilous plants superimposed in luxuriant profusion, contrasts with the scanty shrubs, the open pine forests, and somewhat denser fir forests, all almost devoid of any stratification whatever, which are distributed over the slopes of the latter.—GEO. D. FULLER.

Anatomy of Betulaceae.—The intensive anatomical work among the gymnosperms has forged an unusually effective weapon for attacking phylogeny, and it is beginning to be used in the interpretation of angiosperms, with very interesting results. HOAR[17] has investigated the anatomy of the Betulaceae and has come to the conclusion that the group belongs "near the base of the dicotyledons," and that *Alnus* most clearly illustrates the primitive conditions. In this genus the aggregate condition of rays is either normally developed or in a state of reduction, while in the more advanced genera (*Carpinus*, *Ostrya*, and *Betula*) the aggregate condition persists only in conservative regions or is "recalled by injuries." The conclusion of course depends upon the position of the aggregate ray in the phylogenetic series of ray structures. In the same connection *Casuarina* was investigated, the result being to confirm its low position among the dicotyledons, and also its close anatomical relation-

[15] SHREVE, FORREST, The weight of physical factors in the study of plant distribution. Plant World **19**:53–67. 1916.

[16] ———, The physical control of vegetation in rain forest and desert mountains. Plant World **20**:135–141. 1917.

[17] HOAR, CARL S., The anatomy and phylogenetic position of the Betulaceae. Amer. Jour. Bot. **3**:415–435. *pls. 16–19*. 1916.

ship with the Amentiferae. In fact, this relationship is one argument for the primitive character of the Amentiferae.—J. M. C.

Translocation of sugar.—MANGHAM[18] has attempted to show that adsorption in the complex colloidal system of the protoplasm may play an important rôle in the translocation of sugar in the plant. The discussion is purely hypothetical, and it is rather hard to see how the main hypothesis is to be put on an experimental basis. A quotation from his summary will show the line of his reasoning.

> Adsorption compounds of albumen, lecithin, and glucose are known. It is suggested that in vegetable protoplasm there are present constituents capable of adsorbing sugars from solution. For any given concentration of sugar present in the liquid phase of the protoplasm, and the cell sap continuous with it, there would be a definite concentration of sugar present at the adsorbing surface. Any alteration of concentration in either region would lead to a readjustment of concentration equilibrium, which would be propagated as a wave through the system composed of the adsorbing particles and the solution immediately in contact with them. The rate of propagation of this wave would depend very much upon the degree of approximation of the particles under consideration, and would increase as the distance between them decreased. Connecting threads are assumed to provide a continuous protoplasmic pathway, though they impose restrictions varying with their frequency and tenuity.

Diffusion is generally recognized as being too slow to account for the considerable movement of sugars and other materials in plants. There must be mass movement to supplement molecular movements. MANGHAM's hypothesis does not help us out in this respect because it must assume that "readjustment of concentration equilibrium" is brought about by diffusion so far as movement of the sugar molecule is concerned. The line between adsorption compounds and compounds due to chemical reactions is by no means a sharp one. In fact, it is one of the great battle lines in physical chemistry. One seriously doubts whether anything is gained by his assumption of adsorption compounds. There is much more evidence to support his view that sugar travels from cell to cell mainly by protoplasmic connections rather than by passing through the ectoplast, which is almost impermeable to sugar.—WM. CROCKER.

Physiological diseases.—BONCQUET[19] claims to have solved the mystery of certain plant diseases of the so-called physiological type, such as curly top

[18] MANGHAM, SYDNEY, On the mechanism of translocation in plant tissues. A hypothesis, with special reference to sugar conduction in sieve tubes. Ann. Botany **31**: 293–311. 1917.

[19] BONCQUET, P. A., Presence of nitrites and ammonia in diseased plants. Jour. Amer. Chem. Soc. **38**: 2572–2576. 1916.

BONCQUET, P. A., and BONCQUET, MARY, Presence of nitrites and ammonia in diseased plants. II. Oxidases and diastases; their relation to the disturbance. Jour. Amer. Chem. Soc. **39**: 2088–2093. 1917.

of sugar beets, curly dwarf of potatoes, mottled leaf of potatoes, and mosaic disease of tobacco. Nitrites and ammonia were detected in the juices extracted from diseased plants. Their origin is supposed to be due to the action of nitrate-reducing bacteria, since the presence of these bacteria in the tissues runs parallel to the presence of nitrites and ammonia. The idea is advanced that the characteristic symptoms in all of these diseases are due to nitrogen starvation. The plants are deprived of nitrates taken up by the roots, because of their bacterial reduction to nitrites and ammonia.

The increase of the oxidases in the tissues of plants affected with some of these diseases has been well established. This biochemical phenomenon is easily incorporated into the author's hypothetical scheme. The results of an exhaustive microchemical study, including a histological method for the detection of oxidases, are said to indicate that the increase of the oxidases in the plants affected with bacterial nitrogen starvation is a direct effort of the physiological functions of the plants to overcome the reducing forces of the bacteria. In making such a statement it must be assumed that the oxidation of phenol derivatives by plant tissues is a measure of their power to oppose nitrate reduction. Experiments are recorded and arguments brought forth to show the increased tendency and effort of the diseased plant to make good the loss of nitrates by bacterial reduction. These arguments are not easily followed, as they seem to be based upon the theory that the absorption of salts by plants is a function of the amount of water taken up by the roots.

The announcement of the apparent ease with which supposed causal organisms have been isolated from tissues of plants affected with this class of disease is rather startling, since several years of persistent effort by a number of workers has hitherto failed to establish definitely the parasitic character of these diseases.—CHAS. O. APPLEMAN.